

Applications of Aerospace Technology in Industry

A TECHNOLOGY TRANSFER PROFILE

VISUAL DISPLAY SYSTEMS

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**APPLICATIONS OF AEROSPACE TECHNOLOGY
IN INDUSTRY**

A TECHNOLOGY TRANSFER PROFILE

VISUAL DISPLAY SYSTEMS

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**COLOR ILLUSTRATIONS REPRODUCED
IN BLACK AND WHITE**

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PROFILE HIGHLIGHTS

A brief overview of the visual display field is presented in terms of its economic and technological dimensions. Particular emphasis is directed to a powerful new force—the emergence and rapid growth of computer-driven visual display systems—which has redefined the utility of visual displays (Section I).

In the course of meeting mission requirements, NASA has contributed in a fundamental way to the development of computer-driven visual display hardware systems and their associated software packages. Six specific innovations are reviewed to illustrate the nature of the Agency's contribution (Section II).

Three familiar ways in which the nonaerospace community learns about NASA innovations are described (Section III); and a transfer profile of persons adapting NASA-generated visual display technology is presented (Section IV).

INTRODUCTION

Few people have difficulty understanding the concept of visual display; yet defining the overall technological dimensions of the visual display field is indeed difficult and, perhaps, only marginally valuable. In this regard, this profile surveys the growth of common as well as emerging visual display technologies without attempting to be exhaustive. The major inference is that contemporary society is rapidly growing evermore reliant on visual display for a surprising variety of purposes.

Because of its unique mission requirements, the National Aeronautics and Space Administration has contributed in an important and specific way to the growth of visual display technology. These contributions are characterized by the use of computer-driven visual displays to provide an enormous amount of information concisely, rapidly and accurately. NASA's pioneering efforts in this area have accelerated the use of this complex, highly sophisticated equipment in many nonaerospace applications, including industrial process control, information retrieval and inventory control.

SECTION I. AN OVERVIEW OF THE VISUAL DISPLAY FIELD

A DC-10 recently broke out of the overcast sky at an altitude of 1,500 feet, and dead ahead was Chicago's O'Hare International Airport. Autos moved at a fast clip on the Kennedy expressway, and at a distance, the approach light towers came into view. Suddenly, the craft began to vibrate violently, an alarm sounded, and several instruments indicated trouble. The pilot, copilot, and flight engineer calmly exchanged instructions as they attempted to control the craft. In a matter of seconds, the difficulty was corrected, and there was only a very slight thump at touchdown.

A near tragedy? Not at all! In fact, emergencies like these regularly occur in flight simulators at the United Air Lines Training Center in Denver, Colorado. By means of flight simulators, aircraft personnel can effectively learn how to cope with operational difficulties without endangering life or property. This type of computer-driven visual display system has been instrumental not only in training, but also in sustaining the proficiency of airline flight crews (Miller, April 1972).

Another demonstration of the capabilities of computer-driven visual display took place at the NASA Manned Spacecraft Center in Houston on December 18, 1967. In this case, a test subject "drove" along city streets simulated by computer on a television-type display. By moving a control stick, he directed his path through an urban environment, maneuvered into and through a tunnel, across an overpass, through an underpass, and beneath a building supported on open columns. As a result of this dramatic demonstration, representatives from the UCLA Urban Laboratory Project, Department of Transportation, and General Electric Company concluded that visual simulation offered a powerful tool for understanding and solving problems related to urban planning and highway safety (UCLA, 1969).

These demonstrations indicate the high level of sophistication that has been achieved in visual display systems with the introduction of computer-driven techniques. They also focus on the overriding trend in the visual display field—the emergence and wide use of cathode ray tube (CRT) displays. Of course, the most common use of CRT's is in home television sets. In 1970, 98.5 percent of the households in this country had installed television sets, and only radios, refrigerators, and irons were more commonly found (*New York Times Encyclopedic Almanac*, 1970). The additional use of CRT's in interactive (two-way communication) man-machine systems has opened a broad new horizon of applications ranging from the simulations described above to more mundane, but essential, applications such as ticketing and reservation systems for airlines and hotels.

On a broader level of application, visual display technology has had a pervasive impact upon the quality and efficiency of American business operations. Sales of office copiers, which have become as common as typewriters, have increased 23 percent annually over the past 20 years (U. S. Department of Commerce, 1971). The advent of Computer Output Microfilm—an innovation which allows computer output data to be recorded directly on microfilm—promises to rescue us from inundation by reams of paper computer printouts. The Goodyear Tire and Rubber Company's data center, for example, saved \$250,000 by eliminating 132 printed forms and improved information quality and access through the use of microimager (Richards, December 1972).

Graphic plotters, which display output graphically rather than numerically, date back to 1959. The Teletronix display terminal, used by researchers at Amoco Productions Company to graph oil well exploration data, saves the firm at least \$200,000 per year over hand plotting methods (*Business Week*, June 24, 1972, p. 77). Companies using automatic drafting machines to design electronic circuitry report

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impressive savings in time and cost. Martin Marietta, for example, has reduced its engineering costs for printed circuits by at least 30 percent with this display technology (Lavoie, 1971).

The trend toward more variety in visual communication is particularly evident in education. Chalkboards are being used in conjunction with television sets, and students routinely view filmstrips, videotapes, slides, and transparencies from multimedia libraries. Each year more and more universities are adding extensive courses in film making, and photography is becoming part of the educational process. During the 1970-71 school year, American colleges budgeted over \$66 million for audiovisual equipment and supplies, of which more than 50 percent was for television and camera equipment. Audiovisual expert Thomas Hope predicted recently that the national audiovisual industry could surpass the \$3 billion mark by 1978 (*College Management*, October 1970).

While not yet economically significant, holography is an emerging technology for producing three-dimensional pictures. Its applications range from information storage in computers to nondestructive testing and commercial photography. Presently, holographic products account for less than \$15 million annually and are largely restricted to sophisticated applications. Nevertheless, it is estimated that by the end of the decade, sales will rise to \$95 million as holography becomes more commonly adapted to products such as home video recordings (U. S. Department of Commerce, 1971).

Although the boundaries of the visual display field are difficult to establish, the increasing demand for and reliance on visual communication is easily illustrated. For example, an Automatic Picture Transmission (APT) system was developed by NASA's Goddard Space Flight Center for the Nimbus and ESSA Series weather satellites. The innovation disseminates, on a global basis, current information on local weather patterns through the mode of visual display. The APT system, which has been operational on the satellites for approximately six years, automatically and regularly transmits atmospheric imagery to the Earth. As part of this system, NASA designed a ground receiver which reproduces the imagery as a photographic display.

Anyone around the world can obtain the weather satellite pictures for his vicinity by building the inexpensive receiver described in a NASA publication (NASA SP-5080) or purchasing a commercial unit based on the same design. The National Environmental Satellite Service of the U. S. Department of Commerce estimates that 500 commercial and custom-built receivers either are now operating or will soon be operating in over 50 countries. The most significant installations are those operated by government agencies. These agencies transmit relevant information to different user groups for application to local problems. For instance, the National Marine Fisheries Service uses weather satellite photographs along with information from other sources to determine likely locations of tuna schools. This has enabled the West Coast tuna industry to stabilize its day-to-day rate of catch and decrease search time. (See Transfer Example Summary "Weather Satellite Image Display" in Attachment IV.)

Visual Displays and Computers

The recent emergence of computer-driven visual displays can only be expected to intensify the rapid growth that is already underway. These systems are characterized by sophisticated technology, relatively high cost and largely expanded capabilities. Three factors have shaped the computer's impact on the visual display systems field: the development of sophisticated new computing equipment; improvements in man-computer communication; and the discovery of vast new areas of computer applications.

In the early 1950's, computer systems such as ORDVAC, WHIRLWIND I, and ILLIAC had experimental CRT's; however, the total number of devices was small, there were few manufacturers and applications were limited. Today, by contrast, a myriad of companies manufacture visual display devices for computers. In addition, professional organizations such as the Association for Computing Machinery and the Institute of Electrical and Electronic Engineers have established interest groups specializing in visual display devices and techniques.

The initial conception and use of computer-driven visual display devices was the product of military research. For example, the Semi-Automatic Ground Environment (SAGE) system, built in 1959, incorporated the first large-scale tactical situation display ever used. Responding to demands for an all-out civilian aerospace effort, NASA joined the military in visual display research early in the 1960's. NASA work led to the development of many new visual display devices and techniques, as well as fundamental research on the materials used in such devices. Activities of the Department of Defense and NASA in this area were eventually complemented by many other groups in ways that led to improvements in both hardware design and programming techniques.

While visual displays were once considered luxury features used in only a few computer systems, intensive research and development during the 1960's created a situation in which such displays became vital to many of these systems. At the same time, the control of computer-driven visual displays, once requiring the capabilities of skilled specialists, has become so simplified that nonspecialists are able to operate them with relative ease.

Cathode Ray Tube Displays

By far the most widely used and most versatile visual display unit for computer applications is the cathode ray tube. In 1960, almost none of these CRT-plus-keyboard devices existed outside military/aerospace installations. At present, 85,000 general and special purpose CRT's are in use; it is estimated that by 1976 the CRT terminal population will be nearing the 180,000 mark in business and industry (*Business Week*, June 24, 1972, p. 74). Plotter devices, common until recently, have essentially been relegated to a secondary role in the computer-display field; and flat panel displays require extensive research and development before they will become practical for wide-scale use. Thus, the decade of the 1970's will be devoted to the use of the CRT (Thwaites, 1970).

The CRT displays an image by converting an electric signal into a very thin beam of electrons. As the beam is traced back and forth across a phosphor-coated screen, the phosphor emits visible light to the viewer. The tracing pattern is repeated many times per second in order to provide a steady image on the screen. The image displayed is determined by the electrical signal, which can be produced by a television camera, a computer or other means.

While the main use of the CRT continues to be in television sets, its less well-known, yet vitally important, application in computer systems is pervasive. In the utility industry, for example, the North American Rockwell Information Systems Company is working closely with the Philadelphia Electric Company to build a complete dispatch control center. CRT displays connected with the computer system at this center will give operators instantaneous information concerning the company's entire bulk power complex, as well as a display of projected loads 15 minutes ahead of time. Automated compensation for actual loads is built right into the system (Einwechter and Breece, 1970).

The Canadian Pacific (CP) Railroad's Alyth Yard in Calgary, Alberta boasts a "no hands" operation. Four major terminals in the yard are equipped with teletype and CRT displays, and a monitoring station in the computer room keeps tabs on operation of the system. After an electronic scanner on the "hump" signals the computer which cars are coming to the crest, the computer then assembles complete trains by routing the cars onto the proper sidings as they roll down the incline of the hump. E. H. Shute, CP's rail manager for Alberta, stated that cars are moving faster than ever before; and their traffic volume has increased 35 percent since construction of the automated facility began in 1968 (Welty, 1971).

In education, computer-assisted instruction (CAI) is moving beyond the experimental stage:

CAI made its debut in elementary schools in 1966. A hundred children entering first grade in Brentwood School in East Palo Alto, California found themselves confronted with computer terminals, screens and light pens . . . The pupil also had a pair of headphones by means of which the computer could "speak" to him, if so programmed . . . two-way communication is the key to success in CAI. To communicate, the pupil can use either the typewriter-like keyboard or a light pen . . . CAI is proving its potential at various levels of education, ranging from very small children to graduate students and professional men (Martin and Norman, 1970).

The first comprehensive experiment in computer-based instruction is being undertaken at the United States Air Force Human Resources Laboratory. When operational, an Automatic Instructional System will manage the individualized learning experience of approximately 2,000 trainees. The system provides not only interactive instruction, but it also tailors a multi-media library of slides, audio-visuals, microform, and film strips to fit the needs of each trainee through continuous performance evaluation (Dailey, June 1972).

The Federal Aviation Administration (FAA) plans to spend \$60 million by March 1973 installing computerized radar terminal systems (ARTS-3) at 62 major airports throughout the country. This equipment will automatically display all pertinent flight information and update each aircraft position from the time it appears as a radar blip on the terminal approach area until final touchdown. Floyd Fahey, FAA tower chief in Denver, noted recently that the system will provide a major improvement in air traffic control safety (*Denver Post*, December 9, 1971).

New applications for CRT terminals are being discovered daily. In a recent demonstration of highway design using a combined graphic/CRT display, not only was the road simulated so well that hazardous curves and intersections could be corrected, but probable air and noise pollution patterns were also displayed (Schiffman, January 1972).

It has been estimated that within a decade at least 60 percent of the homes in the U. S. will be wired with cable television systems providing 20 or more channels. Growth of this magnitude would open a whole new vista of possible applications. The wired-city concept, for example, broadens the familiar telephone network into a system that carries both audio and video signals. Part of the promise of the wired-city is two-way communications for a host of services and information needs beyond the obvious entertainment possibilities (National Academy of Engineering, June 1971).

The dramatic growth of CRT's in entertainment, business, and other applications is illustrated in Figure 1-1. Since 1960, the value of CRT shipments in the United States has more than tripled.

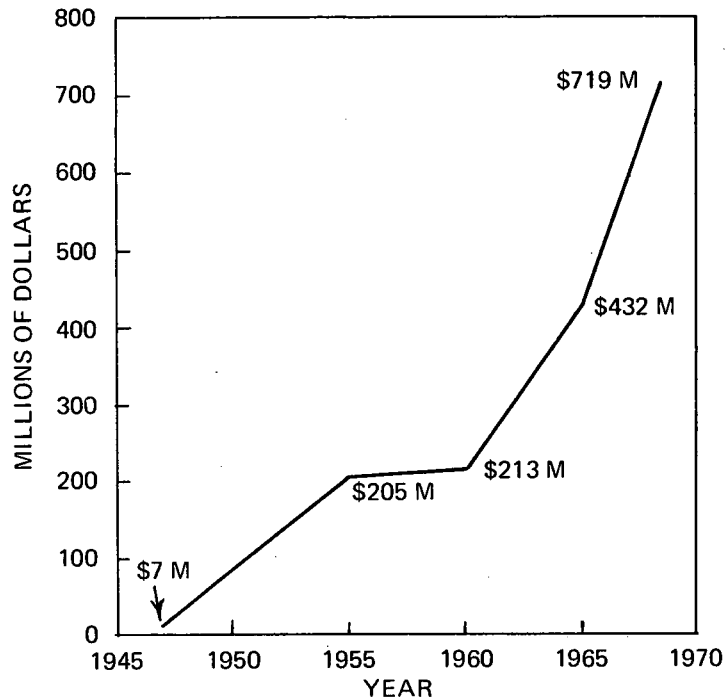


Figure 1-1. Value of Annual Cathode Ray Tube Shipments in the United States From 1945-1968. [Source: *Statistical Abstract of the United States: 1971.*]

But what about the future? Can this growth be expected to continue? Some experts, in looking at new markets, certainly think so:

- The number of companies manufacturing and marketing graphics devices will double between 1969 and 1974; cost (on the average) will be reduced by 50 percent. Storage tubes, color CRT's, and line and character generators will be available in greater variety, at lower cost and on shorter delivery (Hills, 1971).
- The anticipated market for CRT terminals is larger by a factor of three or four over the 1969 market. At least 60, and perhaps as many as 150, different manufacturers are building CRT terminals. A total of 150,000 interactive terminals (CRT plus typewriter) were in use in 1969. In 1975 it is expected to reach 2,500,000 due to increased usage in such areas as inventory control, merchandising, manufacturing, warehousing, etc. (Flynn, 1970).
- Computer-aided design as part of the interactive graphics market will grow to \$50 million-\$75 million by 1975 from approximately \$20 million in 1972, according to the president of a firm which specializes in products for design automation (*Electronic News*, May 15, 1972).

Conclusion

“Some inventions,” science fiction writer Arthur C. Clarke has observed, “represent a kind of technological quantum jump which causes major restructuring of society . . . It is characteristic of such inventions that even when they are already in existence it is a considerable time before anyone appreciates the changes they will bring.”

So it is that time will judge the societal impact of computer-driven display technology, which has grown out of the more traditional display field. And, accompanying this area of progress is the emergence of the cathode ray tube. Two major trends are responsible for the increasing acceptance of CRT's and other computer-driven visual display devices: the rapidly growing use of special purpose computer hardware, which requires new visual display capabilities; and the increasing sophistication of display-oriented computer software.

Section II of this profile examines how developments flowing out of this country's civilian aerospace program have contributed to the two important trends.

SECTION II. NASA CONTRIBUTIONS TO THE VISUAL DISPLAY FIELD

In fulfilling the many requirements generated by manned and unmanned missions during the 1960's, NASA served as a powerful catalyst for technological and economic growth of the visual display field. More specifically, the Agency's needs for computer-based display systems, defined by such operations as mission planning and control, simulation and training, and structural design, called into being unique new systems as well as extended the reservoir of basic knowledge on visual display.

Because of its unique problems, NASA's needs for visual display systems in many cases exceeded the requirements of earth-bound applications. Yet, there are fundamental parameters that are equally important in both aerospace and nonaerospace applications. High reliability and precision, low power, improved contrast, multicolor imaging, and graphics generation are just a few of the demands common to aerospace and other applications such as industrial design, process control, stock market trading and reservations systems. Fundamental requirements for reliability, accuracy, and lower cost, together with a trend toward greater ease of use underpin all display developments. Fulfillment of NASA's requirements has thus created a base which serves the field at large.

Most often the solution of large-scale problems using a computer is accomplished by following one of two approaches. The first is to develop special software packages for a general purpose computer. The second requires the use of a computer specifically designed for a particular problem. Although this latter approach also employs special programming, its main feature is that many functional capabilities are designed into the system. This section examines NASA contributions to both approaches—the development of display-oriented software packages and the development of special purpose computer display systems. Attachment I, by contrast, presents an in-depth study of the technological gains in visual display technology achieved by earth observation programs.

Visual Display Software Packages

The important characteristic of NASA contributions in the area of software packages is that many of the programs would not have been developed were it not for the Agency's unique technical challenges. Once developed, however, many individuals and firms found that they could easily adapt the programs to fit their specific needs. Furthermore, in response to its mandate to provide the widest practical dissemination of its technology, NASA has created the Computer Software Management and Information Center (COSMIC) at the University of Georgia. A more detailed description of COSMIC is presented in Section III.

From the extensive list of available programs, only three have been selected to illustrate new display-oriented applications: Automatic Mathematical Translator (AMTRAN), NASA Structural Analysis (NASTRAN), and the NASA Remote Console System (RECON).

Automatic Mathematical Translator. AMTRAN, a relatively small software package, is a versatile tool developed especially for scientists and engineers. It allows the user to present mathematical equations in a form not requiring specialized knowledge of computer languages. Graphical solutions of the equations are displayed on a CRT. Mathematical operations such as integration, numerical or algebraic differentiation, and inversion can be conveniently performed using this package. Alphanumeric data, as well as vector and point plots, can also be displayed. Anyone who has struggled to visualize the

solution (or set of solutions) to an equation or puzzled over what the integration or differentiation of a mathematical expression actually represents can appreciate the value of obtaining a visual presentation.

NASA Structural Analysis. NASTRAN was designed to analyze and display the behavior of structures used in spaceflight, particularly vehicle behavior under a range of loading conditions. The structures can be of many sizes and forms, including: bars, rods, tubes, plates, panels and shells. The data generated using NASTRAN can be processed by a second NASA program for contour plotting to provide an easily interpreted display of the results. The NASTRAN program has been adapted to run on several large-size computers (e.g., IBM 360/50, CDC 6400 and Univac 1108).

Initial development costs exceeded \$3 million, and on-going maintenance is provided by the NASTRAN Systems Management Office at an annual cost of approximately \$400,000. The average user of NASTRAN spends \$1,700 for program tapes and support documentation.

Since it became available to the public, NASTRAN has been readily accepted for use by a number of government agencies, industrial companies, and by the academic community to solve structural analysis problems. Ford Motor Company engineers, for example, have used NASTRAN to analyze the front suspension system of the company's 1973 trucks for vibration, deflection and stress distributions. Figure 2-1 illustrates the deflection contours of the 1973 Ford truck front suspension arm, as calculated by NASTRAN. A Ford representative has described the outstanding advantage of visual display in computer-based structural analysis: ". . . The plotting program gives us a fast visualization of stress data which otherwise are found in three to six inches of computer printout" (Buell, August 1972).

Remote Console (RECON) System. While programs such as NASTRAN are valuable because previously impossible analyses can be performed and visually interpreted through display devices, the RECON program directs the computer to provide for rapid identification, retrieval, and display of specified information at remote user stations. In the NASA system, a RECON user interrogates a central computer that contains complete up-to-date bibliographic data and abstracts of hundreds of thousands of aerospace reports and journal articles. These entries are continuously collected, indexed and stored. This facilitates active communication between aerospace researchers; reduces dependence on luck, personal acquaintance, and fallible human memories in literature searches; and minimizes the real possibility that a person will inadvertently duplicate or be ignorant of relevant research results.

A RECON user asks about reports and articles by typing instructions and descriptors on a keyboard. The computer replies by displaying relevant citations on a CRT including abstracts of the documents; a teleprinter operated in conjunction with the CRT can provide permanent records of the display. The system works on a time-shared basis, i.e., dozens of users across the country can address the system simultaneously.

Lockheed Aircraft Company originally developed the information science concept which allowed for this computerized access to an expanding technological data file. The first application of this concept was achieved under a NASA development contract for the RECON system. Shortly after the development of RECON for NASA's decentralized scientific and technical information needs, Lockheed developed a similar on-line system, based on their NASA experience, for the U. S. Office of Education. Through its Educational Resource Information Center (ERIC), real-time literature searches are now being made available on an experimental basis at several major universities.

FRONT SUSPENSION—LOWER ARM

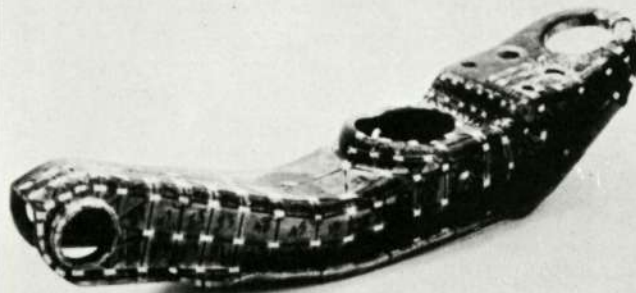
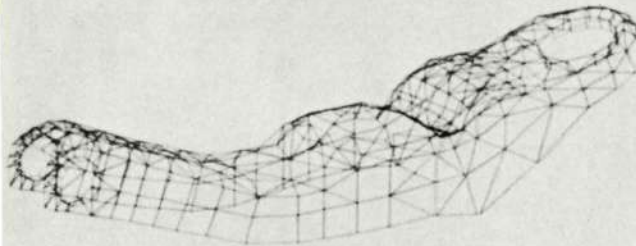


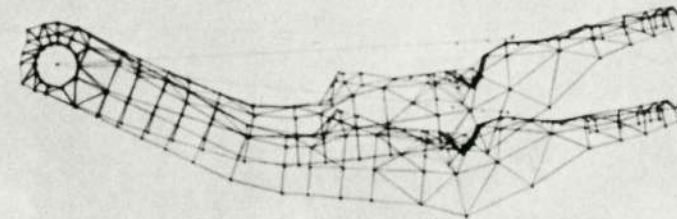
PHOTO OF ACTUAL
PARTS



TOP VIEW
DEFORMED AND UNDEFORMED



PLOTTED
PERSPECTIVE VIEW



SIDE VIEW
DEFORMED AND UNDEFORMED

Figure 2-1. NASTRAN Design of 1973 Ford Truck Front Suspension—Lower Arm. [Source: Ford Motor Company, 1971.]

While RECON facilitates the interaction with the user, a subsystem program—Scientific and Technical Information Modular System (STIMS)—organizes, searches, and retrieves the data in the information file. These two systems are broadly applicable. In fact, remote access to the information data bases maintained by the Department of Justice, Library of Medicine, Department of Labor, Atomic Energy Commission, and the Central Intelligence Agency is now achieved through RECON programming; and where the data base is similar to NASA's, the management of the data base is directly controlled by STIMS programming.

Computer Display Systems

The success of manned and unmanned spaceflight is related in a most fundamental way to the development of computer-based systems that process enormous quantities of data. As space flight became more venturesome, these systems grew more complex. To illustrate the magnitude of this growth, the data processing requirements of two NASA programs—Mercury and Apollo—can be compared. In the early 1960's the Mercury capsule, a single astronaut earth orbiting vehicle, had an on-board computer capable of performing up to one million calculations per minute. By September 1969, the Apollo capsule—a three-man lunar orbiting vehicle—had an on-board system capable of performing 50 million calculations per minute. This trend has likewise accompanied the development of ground-based equipment ranging from launch operations to R&D efforts to program and inventory management.

The keyboard/CRT terminal continues to be a primary input/output device for NASA's vast array of computers, particularly for real-time operations such as prelaunch checkout and mission control. The most widely known control installation in the world, the Mission Control Center at Houston, provided a dramatic illustration of the CRT's efficiency during the Apollo 13 flight. The smooth, integrated relationship between controllers, computers, spacecraft, and astronauts was never more evident than in the problem analysis and flight reorganization for that near tragedy. This relationship depended, to a great extent, on the man/computer interface provided by CRT displays.

NASA's visual display requirements were, in many ways, the first of a kind. Three of the many specialized visual display systems developed to meet NASA mission requirements are discussed in this section. Each of these systems was developed for a different application. Together they illustrate an evolution with respect to the important parameter of control using the keyboard/CRT terminal. The three stages are characterized by: (1) the presentation of fixed data; (2) real-time data gathering and presentation; and (3) the interactive system which gathers, processes, and presents data for interpretation and control by a human operator.

Mass Storage Device System: the first stage. This system was developed by Ampex Corporation for the Marshall Space Flight Center as the display for the NASA Parts Reliability Information Center (PRINCE). It was one of the first applications of professional broadcast video technology in conjunction with computer-controlled accession for a library-style use. In operation, the information stored in a central data bank is selected and displayed at any of the remote keyboard/CRT consoles. The crucial elements in the operation of PRINCE are accession by a small computer and a tape transport mechanism, which presents a selected tape to a vidicon tube for transmission to the CRT. The important new capabilities provided by the Ampex system include significant decreases in the response time for information access, a reduction in size of the centralized records storage facility, and a larger geographic area of service. A new Ampex division, Videofile Information Systems Division, has refined and successfully marketed this display system to handle law enforcement, hospital, railway and insurance records. (See Transfer Example Summary "Videofile" in Attachment IV.)

Saturn V Display System: the second stage. Sanders Associates, Incorporated, working under a NASA contract from 1965 to 1967, developed the visual display system used in the Saturn V pre-launch checkout. This system provides the interface between checkout personnel and computers, thereby facilitating the real-time processing of test measurements from thousands of sensors attached to the Saturn V booster. Approximately 2,000 discrete input signals are processed, and a like number of outputs are fed back to the booster.

NASA's extensive pre-launch checkout complex includes a test site computer that receives and processes data from the booster. The output from this computer is transmitted, along with other data, to computers in the control complex at the Kennedy Space Center and to the Marshall Space Flight Center. Several Sanders systems are located at each facility to display these data and other computer outputs. Each Sanders system has between two and fifteen interconnected keyboard/CRT terminals with a central data processor, distribution and interface logic, refresh memories, and data conversion equipment. The latter provides hard copy, slide reference, and closed circuit TV displays.

The Sanders system parcels out data to remote terminals so that experts can make go/no go decisions for the myriad of Saturn V components. Furthermore, graphs, tabular data, and vectors can be mixed in the CRT display. The operator selects a format by using the keyboard and inserting software selection cards into a slot on the terminal; self-testing routines can also be performed on each terminal to insure proper functioning. Sanders Associates has developed a whole product line of information display systems based on this system. (See Transfer Example Summary "Saturn V Checkout Display" in Attachment IV.)

Universal Control and Display Console: the third stage. The General Electric Company, under NASA contracts in 1970 and 1971, developed the Universal Control and Display Console (UCDC) for NASA's work on the Unified Test Equipment (UTE) checkout concept. The complete UCDC system consists of both the hardware and software to verify proper operation of several complex systems for the Space Shuttle and other advanced programs. The console is designed for efficient use by a single operator, but the modular design permits expansion. It is capable of supporting all phases of spacecraft development test activity, unit level testing, subsystem testing, and factory acceptance and launch area testing, including refurbishment. Test management and test information can be totally controlled by the UCDC system.

The system consists of both a Display and Control Module (DCM) and an Acquisition and Control Module (ACM) as shown in Figure 2-2. The capability of the UCDC system is integrally related to specialized software packages. Continuing software developments further enhance the utility of the system. The DCM provides the data processing and control capability required to perform closed-loop automated testing, displays system status, and permits real-time format selection and test modifications by the operator. Since the equipment is compact and mobile, it can be economically moved to new locations where it can quickly be placed in operation.

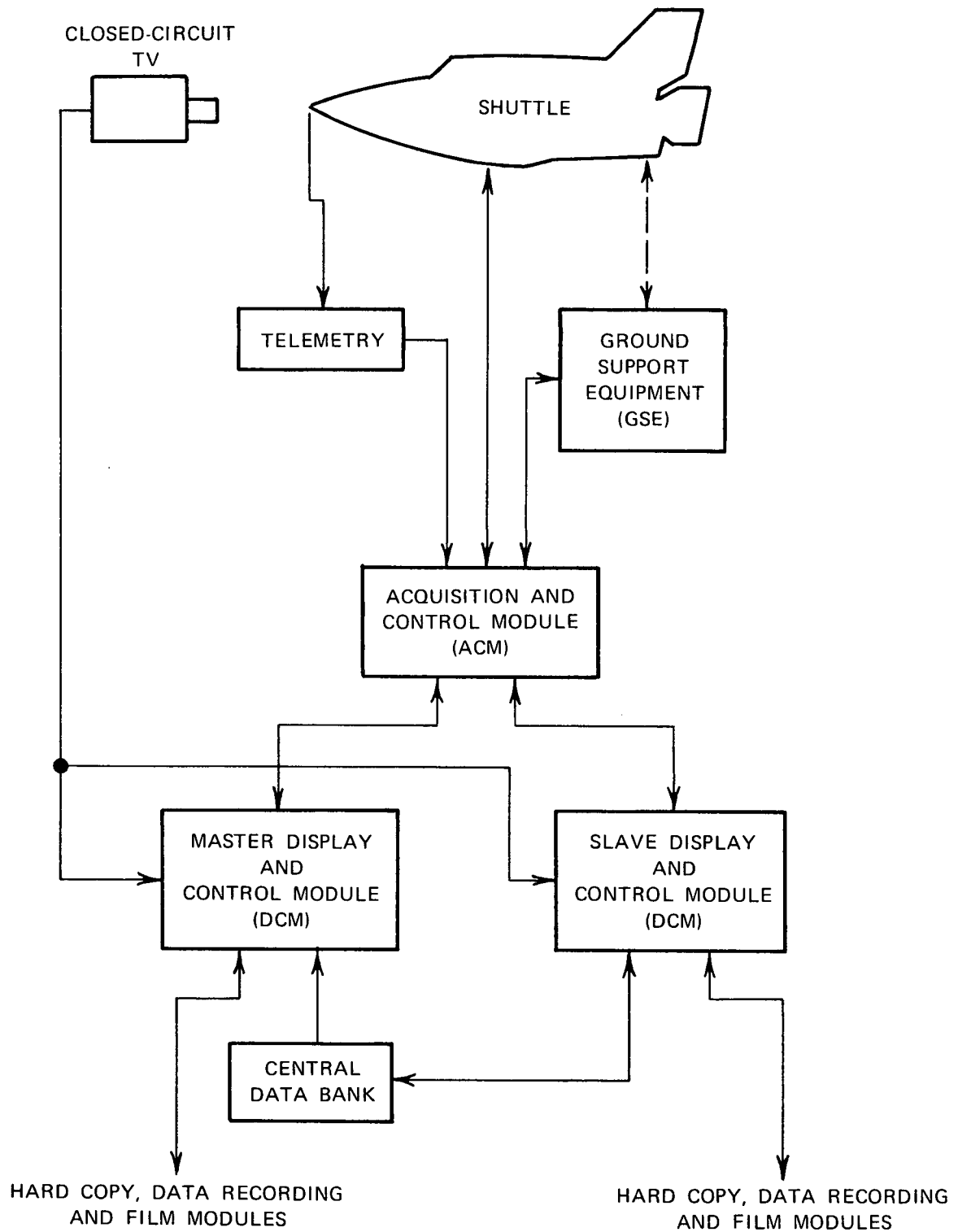


Figure 2-2. Universal Control and Display Console System. [Source: General Electric, 1971.]

Figure 2-3 illustrates how information can be displayed in several forms utilizing two color television monitors. Internally generated displays are constructed from alphanumeric characters, status symbols, analog value symbols, special pictorial symbols, and time varying or X-Y data plots as shown in Figure 2-4. The symbols can be combined to form an unlimited number of display pages, each of which is selectable by the operator. In addition, externally generated images from closed circuit television cameras or other consoles can be displayed.

The ACM provides the command/data interface with the test article and its associated ground support equipment. As with the DCM, the ACM is modular and expandable, allowing the UCDC to be adapted to a variety of multiple data inputs including serial or parallel formats. Additional functions provided by ACM include the formatting of data for DCM processing and the tagging of data to denote routing for subsequent display processing, critical measurement processing or recording. The ACM is programmable and, therefore, quickly tailored to changing test requirements. Verification of all program loading operations as well as individual commands is accomplished automatically to insure validity prior to execution.

After initial development of the NASA system, General Electric started development of a commercial version of the UCDC. (See Transfer Example Summary "Universal Control and Display Console" in Attachment IV.)

Summary

Intensive engineering efforts by NASA and its contractors during the 1960's have contributed in a major way to the rapidly growing use of computer-driven visual display devices. In particular, NASA has developed display-oriented software packages, as well as hardware systems, which have been easily adapted to fit the specific needs of private industry. Although this section has focused on only a few specific NASA innovations, the nonaerospace community has applied many of the Space Agency's developments in the field.

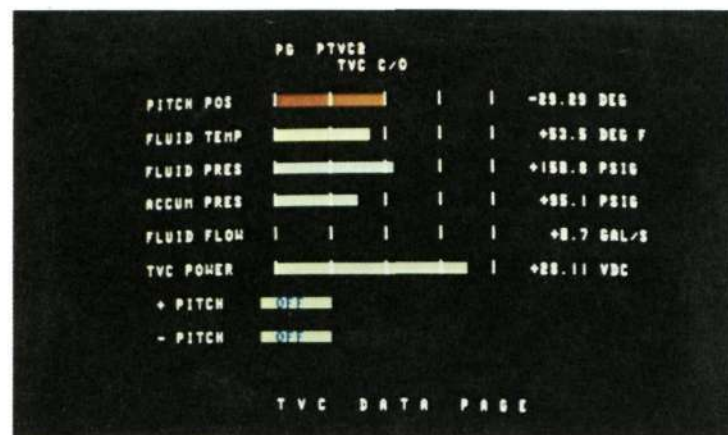
Section III of this profile examines how people outside the space program acquire information about these NASA contributions; while Section IV considers some of the ways in which NASA-generated visual display technology is used in nonaerospace applications.



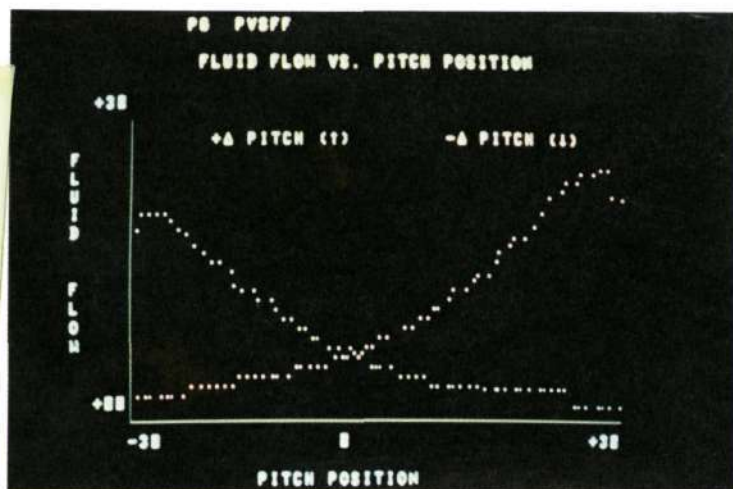
Figure 2-3. Universal Control and Display Console with Two Color CRT Monitors. [Source: General Electric, 1971.]



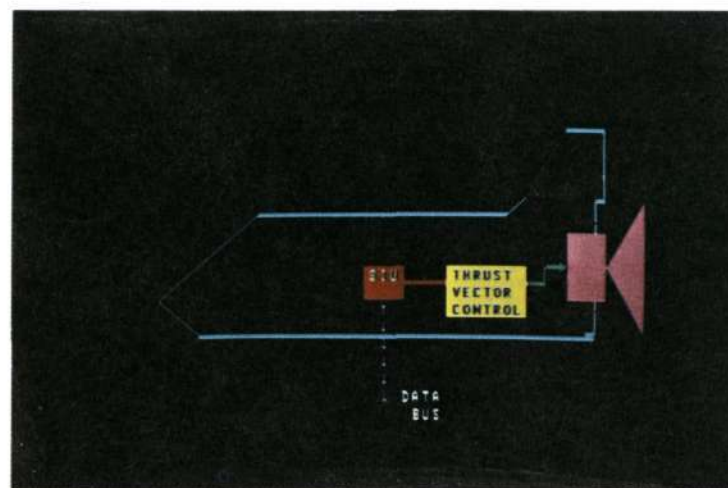
KEYBOARD WITH TVC TEST FUNCTIONS



TVC DATA DISPLAY



TVC DATA TREND PLOT



SPECIAL GRAPHICS DISPLAY

Figure 2-4. Universal Control and Display Console Showing Typical Features and Capabilities. [Source: General Electric, 1971.]

SECTION III. COMMUNICATION OF NASA VISUAL DISPLAY CONTRIBUTIONS

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The transfer of technology originally developed for the space program is facilitated by many communication media. NASA has developed its own system for such communication including technical publications, regional dissemination centers, and special services like the Computer Software and Management Information Center (COSMIC). Outside the formal NASA system, transfer is also initiated by numerous mechanisms including technical and trade journals, seminars and conferences, the movement of people, and by other vehicles which are not yet completely understood. This section will describe three familiar channels of communication—NASA publications, COSMIC, and contractor diversification activities—which disseminate NASA visual display technology.

NASA Publications

The research results from most space program projects are communicated through a variety of NASA publications written by in-house and contractor personnel. Between 1963 and 1971, for example, the number of documents reporting technical advances related to cathode ray tubes and computer display technology included: 36 Contractor Reports, 14 Technical Memorandums, 8 Special Publications and 7 Technical Notes.

One of the primary techniques which NASA has used to disseminate visual display technology outside of the aerospace community is the Tech Brief. A Tech Brief, which announces a NASA innovation and potential new applications for the technology, is widely distributed to individuals who have indicated an interest in the same general field of technology. When an individual discovers visual display technology in a Tech Brief that is relevant to his interests, he can request a Technical Support Package (TSP) which further describes the technology.

Between 1963 and late 1971, 130 NASA Tech Briefs announcing the development of visual display technology had been issued. Figure 3-1 shows the number of Tech Briefs produced by each NASA center, as well as whether they originated from in-house or contractor research. An analysis of transfer activity in the nonaerospace community related to visual display technology described in the TSP's is presented in Section IV.

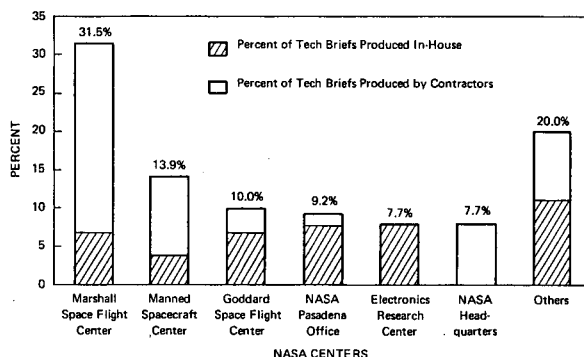


Figure 3-1. Production of 130 Visual Display Tech Briefs, by NASA Field Center, Showing In-House Versus Contractor Origin.

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COSMIC

The Computer Software Management and Information Center (COSMIC), located at the University of Georgia, was established by NASA to make available to users of computers the many programs developed for the Space Agency's needs. In serving as a central clearinghouse and dissemination outlet for computer programs and related documentation developed by NASA and its contractors, COSMIC maintains an inventory of items which are operationally verified and potentially valuable in a wide range of commercial and educational applications.

COSMIC has established a firm base of support in the industrial, educational, and business communities with more than 20,000 items disseminated to date. Since program development costs are borne by NASA, software packages can be acquired for the cost of reproduction and distribution. The Department of Defense recently joined NASA in this effort by agreeing to make available to the public, through COSMIC, certain programs developed originally for DOD requirements.

A particularly successful computer program—NASTRAN—illustrates how the operation of COSMIC facilitates the transfer of technology created originally for Agency requirements (see Section II). The operation of COSMIC in validating and packaging NASTRAN application programs represents a planned effort to make available new analytical and computing technology to organizations outside the aerospace sector; while the NASTRAN technology is diffusing within the aerospace sector, organizations outside aerospace also have timely and economic access to the innovation.

NASA Contractor Diversification

When a nonaerospace company first learns about a NASA innovation, the first step generally involves an evaluation of the technology to see if it is consistent with the company's existing product line and fills a market need. By contrast, the company which conducted the original development work under NASA contract has both a residual expertise and a timely understanding of the market. In fact, many companies use military and aerospace research contracts as a stepping stone in the development of commercial products. Likewise, some NASA contractors conduct regular in-house reviews to consider potential commercial applications for technology developed under NASA contracts.

Contractor diversification activities in the visual display field concentrate on the several important marketing steps for promising innovations. Chief among these steps are the identification of potential markets, adaptation of an innovation to meet new application requirements, and an economic analysis for both production and marketing. Several distinctive methods have been used by contractors to facilitate such adaptation and analytical activities: creation of an in-house marketing group for an innovation; contractual agreements with nonaerospace companies serving the target market; purchase of a subsidiary company serving the target market; and cooperation between space and nonspace divisions in the same company. Regardless of the method used, once the steps are successfully negotiated, the technology is communicated to a new market audience through its embodiment in a product.

A good example of the interdivisional method is provided by the General Electric Company. The Houston Programs Group in the company's Missile and Space Department recently designed and built the computerized display and control system (UCDC) described in Section II. Two new markets for the system are now being investigated through interdivisional cooperation. The G. E. Houston group is working with both the Industrial Process Control Department to develop UCDC for electric power transmission applications and with the Transportation Systems Department for rapid transit system

applications. This intracompany transfer activity is facilitated by the fact that these two General Electric departments had previous experience in the potential markets for UCDC.

Conclusions

The transfer of NASA-generated visual display technology is achieved through numerous communication channels. This section has focused on three specific media systems which are disseminating technological information to the nonaerospace community. In its effort to document and disseminate information to the private sector, NASA attempts to reach different specialized audiences with technical knowledge concerning problem-solving. Each effort is designed to simplify the adaptation phase of the transfer process for different target groups, and each contributes to the access and distribution of technical resources beyond the aerospace sector.

In order to understand more fully the activities in the private sector, Section IV will present a more detailed analysis of the transfer process for visual display systems technology communicated through NASA's Tech Brief-Technical Support Package program.

SECTION IV. A TRANSFER PROFILE

After reviewing the variety of channels used to communicate space program innovations in visual display technology, it is appropriate to examine some ways that individuals have applied this technology outside the space program. This section considers only transfer activities associated with the NASA Tech Brief-Technical Support Package (TSP) program. It is important, though, to emphasize that transfer activities associated with nonaerospace uses of TSP's represent only a portion of the total transfer activity involving NASA-developed technologies. In this regard, Attachment IV presents a broader picture of the many ways people acquire and use NASA-generated technology.

TSP Users Survey

By the end of 1971, persons outside the space program had made 3,594 requests for TSP's associated with the 130 Tech Briefs reporting NASA-supported contributions to the visual display field. Mail questionnaires were sent to approximately 40 percent of the TSP requesters six months after they had ordered the documents. This time delay was considered sufficiently long to permit TSP users to reach tentative conclusions concerning applications of the display technologies presented. More than one-half (764) of those contacted responded to the mail questionnaire. To amplify the specific nature of transfer activities, telephone interviews were conducted with those respondents who indicated on the questionnaire that they had made substantial progress in using the technologies to solve specific problems.

Transfer Stages Concept

Before describing specific transfer activities involving visual display technology, it will be useful to examine the progression of stages associated with such activities. Once this idea is clarified, it will be used to place specific transfer examples in an appropriate frame of reference.

The process of transferring a technological contribution may be described as a series of related activities that progress through four different stages. Figure 4-1 illustrates this "transfer stages" concept.

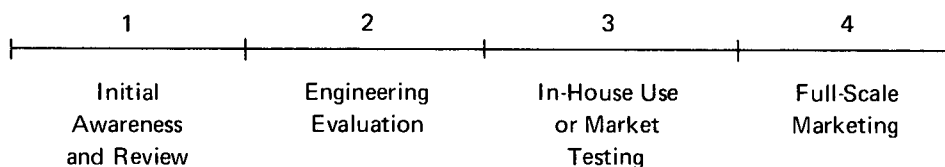


Figure 4-1. Four Stages in Technology Transfer.

Stage one is characterized by an initial awareness on the part of a potential innovator working in the private sector of the existence of a new contribution to a field of technology. During this transfer stage, the innovator may search for additional information concerning the technology in order to determine its relevance to his interests. The second stage involves adaptation of the new technology to fit the non-NASA requirements. A transfer experience progresses into stage three under one of two conditions: either an organization begins to use the adapted technology in its own operational activities (e.g., industrial processing), or an industrial firm begins to market test prototype versions of the adapted

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innovation. Only those firms with plans to market a product incorporating the adapted technology ever progress into the fourth transfer stage.

Throughout the description of transfer stages, distinctions have been made between two kinds of transfer activities: adaptation and diffusion. Adaptation activities, in which a public sector-generated technology is shaped to fit the requirements of the private sector, span the first three transfer stages. This adaptation phase usually is conducted by a private sector firm (i.e., commercial or industrial); and, importantly, a technology originating in the public sector cannot emerge and begin diffusion throughout the nonaerospace sector until the adaptation phase is complete. The diffusion phase of transfer for the adapted innovation begins when other firms or organizations adopt the transformed innovation—an activity occurring in the fourth stage. For example, a NASA innovation in the computerized display and control of pre-launch checkout for a rocket and launch system must undergo a process of adaptation before it can be utilized by a process control engineer in the petroleum industry; following adaptation, social and economic constraints are then operative which affect the diffusion of the transformed display innovation into different manufacturing industries.

Survey Results

A profile which illustrates the different stages of transfer activities identified in the questionnaire survey of TSP users is presented in Figure 4-2. It can be seen that the greatest frequency of transfer activity in visual display was associated with the “awareness” stage of the transfer process.

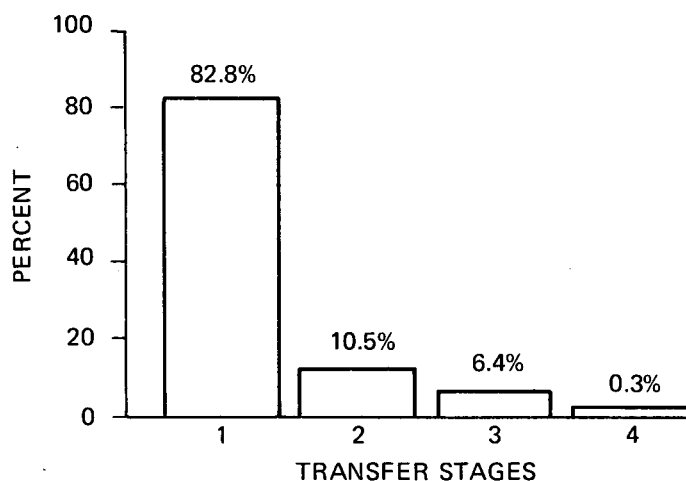


Figure 4-2. Transfer Profile of 675 Persons Who Reported Using TSP's Related to the Visual Display Systems Field.

As a point of interest, six of the 130 Tech Briefs disseminated generated 2,075, or 58 percent, of the total TSP requests. They are: 67-10005—“Digital Computer Processing of X-Ray Photos”; 67-10568—“Graphic Visualization of Program Performance Aids Management Review”; 68-10069—“Principles of Optical-Data Processing Techniques”; 69-10594—“Airborne Fraunhofer Line Discriminator”; 70-10030—“Contourograph Display System for Monitoring Electrocardiograms”; and 70-10476—“Visual Display Panel Functions as Computer Input/Output Device.” Although over half of

the requests for TSP's associated with visual display Tech Briefs can be attributed to these particular six, a profile illustrating the user's transfer activities is not significantly different from the total profile shown in Figure 4-2.

A stage one transfer example illustrating the initial steps required for new product development involves the Magnavox Company in Silver Spring, Maryland. A senior staff engineer with Magnavox discovered a NASA Tech Brief (70-10464) describing a single gun color TV system while he was conducting a literature search for a proposed new product, a cable TV system for biomedical applications. The development was shifted to another group in the company which plans to use flat panel plasma displays. The engineer has no current plans to use the single gun technology. (See "Single Gun Color CRT" Transfer Example Summary in Attachment IV.)

Progress into stage two is characterized by an increased commitment in available resources. Tek-Dayme Research Associates in Carbondale, Illinois is constructing a prototype of an improved electroencephalograph display system based on the conceptual system described in a NASA TSP (70-10447). The University of California Medical School is funding the development of the prototype. Tek-Dayme, in turn, may conduct market studies after the technology has been embodied in a prototype. (See "Improved EEG Monitoring Method" Transfer Example Summary in Attachment IV.)

Approximately six percent of the respondents in the survey indicated their transfer activities had progressed into stage three. In many cases, the nature of the technology itself limits the transfer process in the third stage. A case illustrating this point involves Ford Motor Company's use of the NASA Structural Analysis Program (NASTRAN). Ford engineers are using NASTRAN to conduct quality assurance analyses of automobile frame designs and other automobile components. However, as long as Ford has no plans to market the adapted computer program, it cannot enter the fourth transfer stage. (See "NASTRAN" Transfer Example Summary in Attachment IV.)

By contrast, another transfer example can be cited that shows how some companies are laying the groundwork for successful stage four activities in stage three. The General Electric Company has published advertising literature and engaged in sales discussions with potential customers for a new, computerized display and control system which the company developed, in part, under NASA contract. A good market potential exists in the areas of industrial process control, electric power grid control and other complex systems. (See "Universal Control and Display Console" Transfer Example Summary in Attachment IV.)

A few companies are currently engaged in stage four transfer activities. Typically, the high development costs of complex computerized display systems and the rapid emergence of new capabilities as part of the space program have tended to place NASA contractors in a unique marketing position. For example, Sanders Associates, Incorporated in Nashua, Massachusetts has developed a whole product line of computerized information display systems based on the system which it developed under NASA contract for the pre-launch Saturn V checkout operation. The Sanders units are now being used in hospitals, industry, and other information handling operations. (See "Information Display System" Transfer Example Summary in Attachment IV.)

Conclusion

Several transfer examples have been cited to illustrate the wide range of activities in which organizations have attempted to commercialize on NASA-generated visual display technology. Although

NASA's contributions are widely applicable, progress through the four stages of transfer depends on a time-consuming integration of many technical, management and socio-economic factors. The stages of adaptation represent decision points in technical problem-solving. Each successive stage requires greater commitment of resources by an organization, and therefore, its achievement is inherently less probable in the short run. This is true even in cases where the technology can provide substantial benefits to the recipient organizations.

SECTION V. A FOCUS ON ISSUES

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This profile development has provided a unique opportunity to observe the emergence of an economic and socially significant technology: computer-driven visual display systems. The importance of these visual display systems is indicated by the many different industrial sectors that now routinely employ them in design and control applications. And the advantages associated with "seeing" instead of having to analyze clues or data about a situation strongly suggest that the use of these displays is only just beginning.

NASA's influence on the advancement of visual display technology has been particularly strong, stimulated by the complexity and risk of manned spaceflight. The Agency was confronted with unique and seemingly impossible requirements such as the need to control thousands of interrelated mechanical, electrical, and chemical systems before and during a space mission. Computer-driven visual display technology has been crucial in obtaining the necessary analyses and control of these systems; and as a result, this technology was directly advanced by the mission-oriented research and development efforts of NASA. Both programming concepts and hardware developments have been utilized to meet, more effectively, the needs found in manufacturing, service industries, process control, public agencies and education.

Two different modes of technology utilization have been observed in the preparation of this profile. In one mode, NASA contractors have moved quickly to introduce certain hardware developments commercially; and, in the other mode, software for obtaining new types of visual displays has been effectively captured for nonaerospace use through the formal NASA Technology Utilization Program.

ATTACHMENT I
NASA CONTRIBUTIONS TO VISUAL DISPLAYS
USED IN REMOTE SENSING

31

Visual display technology, and particularly computer-driven visual displays, form the key building blocks of another field that is emerging on the national scene: remote sensing of the environment. This attachment briefly reviews the technology of remote sensing and examines the role of computer-driven displays in converting the potential of remote sensing technology to practical applications.

Very early in the space program it was realized that a new view of the Earth was possible, a view more comprehensive than man had ever experienced before: the Earth could be visualized in its entirety. Scientists began to ponder on the usefulness of this new capability. Could the ability to view larger and larger parts of our planet be directed toward the solution of complex problems caused by a deteriorating environment, dissipating natural resources and an expanding population? The answer to this question was definitely yes. While the impact of remote sensing is only beginning to be realized, its promises have grown as scientists and engineers developed the tools needed for a better understanding of the earth's resources and environment.

For most applications, the important contribution of remote sensing is a synoptic, or broad-scale, image as opposed to the conventional aggregation of local information into a composite image. Two regional maps produced by the United States Geological Survey from Gemini and Apollo photographs illustrate this point. One map for the southwestern United States and northern Mexico covered a region that had previously been mapped using smaller area conventional maps. The synoptic overview provided by satellite photos revealed very large geologic features that were previously undetected. The second map, for the Peruvian Andes, covered a region with very limited existing maps. Geologists estimated that the comprehensive information on geologic features revealed in the map of Peru would have taken years of aerial photography or decades of ground survey work for duplication.

In early studies, photography was the most popular remote sensing tool. Color photographs obtained by Gemini astronauts demonstrated the feasibility of satellite surveys for agriculture, oceanography, hydrology, geology and cartography. Since then, a number of new instruments have been employed to record energy signatures that cannot be observed by the human eye or recorded by conventional photography; and innovative new techniques for enhancing images to highlight a phenomena of particular interest have become operational. It is in this latter regard that remote sensing has called into being major advances in visual display technology.

Remote Sensing

Remote sensing is possible because all matter, in its own distinctive way, absorbs, emits or reflects electromagnetic radiation. An object's specific distribution of reflected or emitted electromagnetic radiation is commonly called its spectral signature. This "fingerprint" is what allows objects to be differentiated from each other and can also indicate the size, shape, density, surface regularity, moisture content, and other properties of an object (NASA EP-93). Figure I-1 indicates some typical spectral signatures that have been identified by remote sensing. Cotton leaf, for example, has a different signature from that of beach sand or clay; and healthy vegetation can be distinguished from diseased plants.

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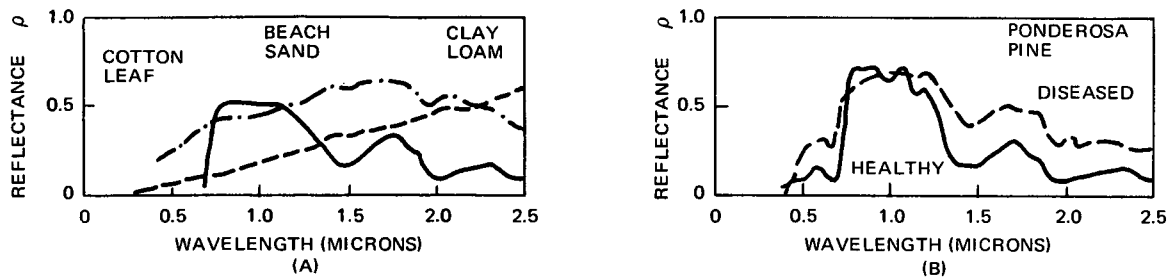


Figure I-1. Spectral Signature for: (A) Vegetation Target and Soil Backgrounds, and (B) Healthy and Diseased Vegetation. [Source: Peacock and Withrington, 1971.]

The human eye and conventional color photography pick up electromagnetic radiation in a relatively narrow band of the electromagnetic spectrum (see Figure I-2). Nonetheless, color photography can tell an analyst many things about vegetation, soil conditions, water depth and mineral deposits. Urban areas can be distinguished from farm fields or a recently cleared woodland.

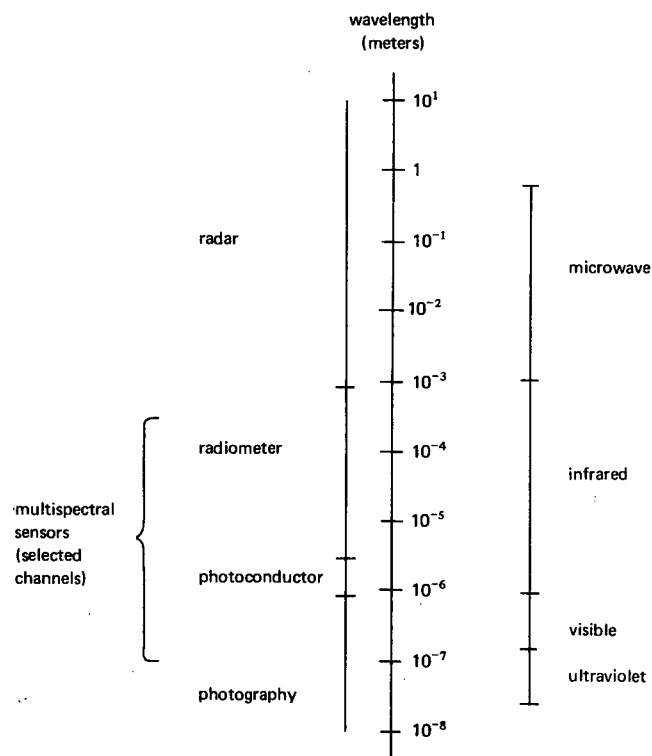


Figure I-2. Regions of the Electromagnetic Spectrum and Associated Remote Sensors.

While color photography is and will continue to be important, remote sensing technology would be seriously limited if energy outside the visible region could not be detected. This situation led NASA to experiment with sensors that show much more about the Earth than meets the eye. Infrared sensors, for example, cover a band of electromagnetic energy that is wider than the visible band. Although infrared rays are invisible to the naked eye, they can sometimes be felt as heat. Actually, everything on the Earth emits infrared rays, including the polar icecaps; and infrared instruments have been made so sensitive that satellite-borne sensors were able to trace the outline of the Gulf Stream for more than 1,000 miles. Ultraviolet energy is most familiar as that part of sunlight that causes sunburn. Ultraviolet sensors have been used to detect the presence of invisible pollutants such as carbon monoxide and sulphur oxides in the atmosphere.

Whereas photography, ultraviolet, and infrared sensors are considered “passive” because they measure energy emissions from an object, microwave equipment is characterized by its “active” mode of measurement. Radar, for example, sends out a signal and then measures the way it is reflected. Radar has been used to detect surface vegetation and subsurface geologic formations as well as oil spills.

Sensing energy across a wide range of the electromagnetic spectrum has unveiled new vistas of knowledge about the Earth. However, the ability to collect data with remote sensors is rapidly outpacing the ability to process it. Figure I-3, for example, illustrates the rapid growth in data production by recent remote sensing programs.

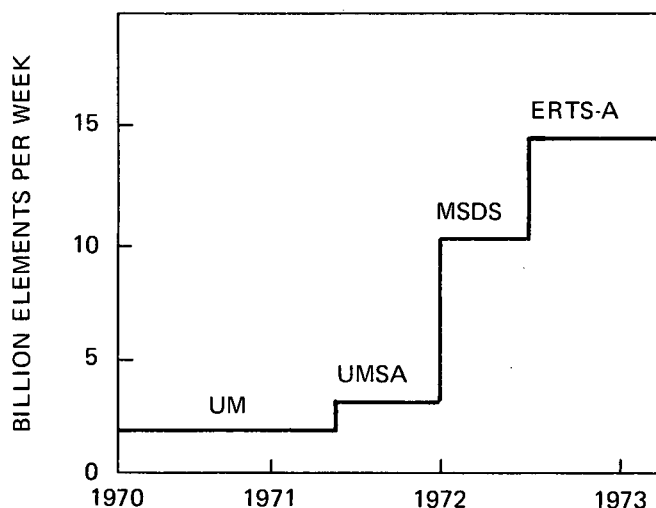


Figure I-3. Cumulative Multispectral Sensor Data Rate Capacity Based on Four Hours of Data Output Per Week: the University of Michigan (UM) 18-Channel Multi-aperture Scanner, the University of Michigan Single Aperture (UMSA) 12-Channel Scanner, the MultiSpectral Data System (MSDS) 24-Channel Scanner, and the ERTS-A* Combination of a 3-Channel RBV with a 4-Channel Scanner. [Source: Marshall and Kriegler, 1971.]

*The designation for ERTS-1 prior to launch on July 23, 1972.

Data Processing

New knowledge about our planet will undoubtedly be controlled by the rate at which remotely sensed data can be converted into useful information. A myriad of techniques are available or are being developed for this purpose. Techniques range from manual processing of photographs through interactive man-machine analysis using both man and computer processing of imagery to fully automated analysis of the data. These techniques provide an analyst with a library of image processing options which can be linked, modified, or augmented to facilitate interpretation of selected information.

Creating useful images from remotely sensed data generally includes computation of geographic coordinates of image centers as well as operations such as digitizing, registering, rectifying and standard conversions. Digitizing, for example, involves converting the sensor data or imagery into a format suitable for storage and processing by a computer. The stored digital data can then be converted into permanent visual records by a line printer, plotter, or photographic processor at any stage in the subsequent processing; or they can be temporarily displayed on a TV monitor.

Once created, the imagery may be modified to give it characteristics that simplify analysis and interpretation. In a processing technique called "neighborhood operations," a point is classified as a noise point if it differs from all eight of its nearest neighbors by more than a prescribed threshold. The indicated gray value of the noise point is then replaced by the average of its eight disharmonious neighbors (Viglione, 1972). Table I-1 indicates some of the other procedures which are used to improve the quality of machine-processed imagery and give it characteristics that simplify analysis and interpretation.

TABLE I-1. MANIPULATIVE IMAGE PROCESSING PROCEDURES*

Name	Description
Distortion removal (including rectification)	Geometric correction for attitude errors and non linear sensor geometry
Gridding	Adding earth coordinates to imagery
Mosaicing	Merging contiguous images into larger formats
Smear removal	Compensation for image motion caused by velocity vector
Enhancement	Alteration of image fine structure to aid heuristic analysis
Scaling	Changing apparent size of imagery
Contouring	Connecting iso-value data points
Noise removal	Recognize and filter unwanted data
Registration	Overlay two or more images to maintain coincidence
Correlation	Determine similarity or difference between two given functions
Parameter extraction	Determine unique regional characteristics (e.g., area, perimeter, length, centroid, etc.)
Change discrimination	Determine time dependent changes of interest in given regions
Border following	Partitioning into regions of like class
Additive color	Producing true or false color images from multispectral sources

*Source: Kuehn, Omberg and Forry, 1971.

Corn Blight Watch Experiment

Many advances in remote sensing technology have been made in recent years, but only the 1971 Corn Blight Watch Experiment assembled all the elements of an information system using remote sensing into one package. This experiment grew out of a serious and unexpected outbreak of southern corn leaf blight during July and August of 1970. At that time, the nation's corn crop was reduced by 15 percent as a new race of this previously minor disease swept through several southern and Corn Belt states.

The U. S. Department of Agriculture, NASA, the Laboratory for Applications of Remote Sensing (LARS) at Purdue University, and several other organizations joined forces to conduct an experiment that included remotely sensed measurements, ground observations, a sampling model, data analysis, and an information dissemination network. An intensive study area was selected, and multispectral scanner data were collected along with ground observations and color infrared photography. A comparison of the various observations is shown in Figure I-4. Figure I-5 illustrates a detailed comparison of infrared photography and machine-processed multispectral scanner data.

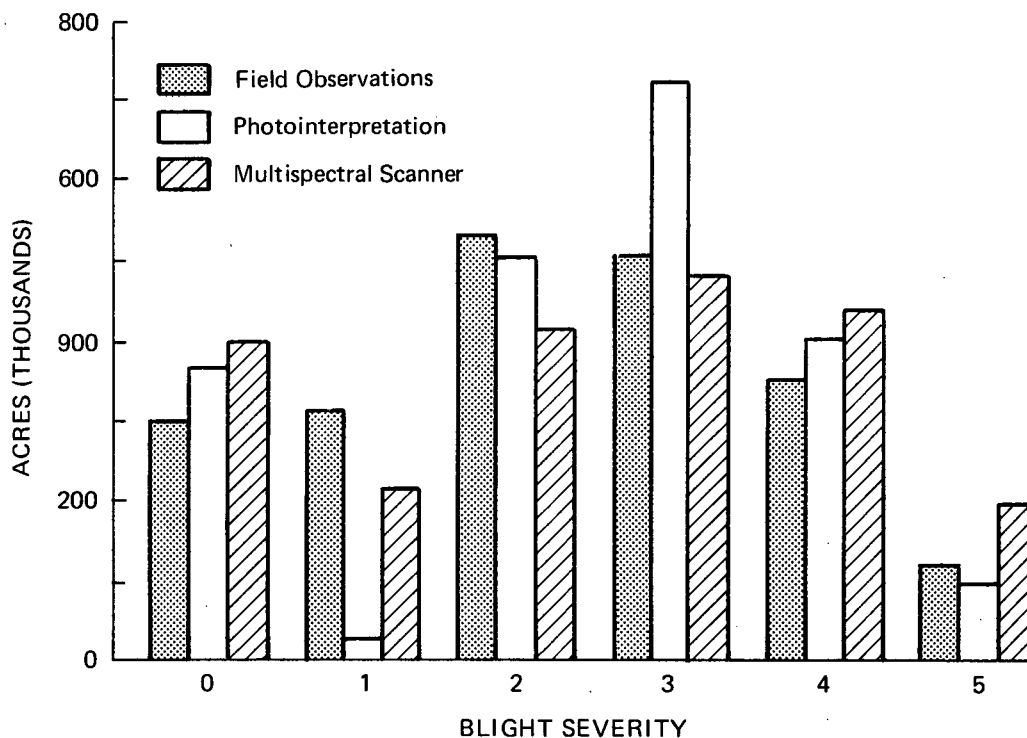


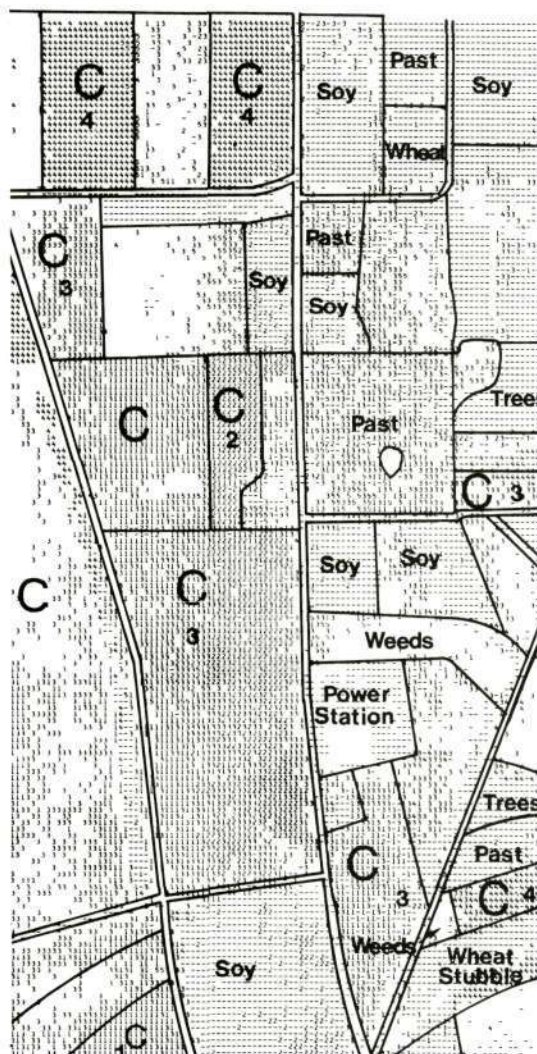
Figure I-4. Comparison of Field Observation, Photointerpretation, and Machine Analysis Estimates of Corn Acreage in Individual Blight Classes for the Intensive Study Area, August 23 to September 5, 1971. [Source: MacDonald, *et al.*, 1971.]

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POWER STATION

A brown-toned rendition of a color infrared photograph obtained by a NASA aircraft on August 9, 1970 as part of a multiagency project to monitor the spread of Southern Corn Leaf Blight. The scene is a portion of Greene County, Indiana with a scale of 1:24,000. An arrow indicates the power station identified in the machine-processed image so that corresponding areas may be compared.



Computer printout of crop type and corn blight information for the same portion of Greene County, Indiana. This information was automatically processed by the method of spectral analysis using digitized data from an airborne multispectral scanner. The letters indicate crop type (e.g., C represents corn), while the numbers refer to four blight severity classes (e.g., C1 represents the none to slight class, while C4 represents severe blight).

Figure I-5. Comparison of Infrared Photography and Machine-Processed MSS Data.
[Source: Bauer, December 1972.]

Using these techniques, investigators were able to monitor accurately changes in the severity of the corn blight more rapidly than ever before. Figure I-6 illustrates how the corn blight pattern changed between July 26 and August 27, 1971. As a result of this experiment, it was concluded that remote sensing is capable of reliably identifying and measuring the extent of agricultural crops and land use, as well as certain instances of crop stress (MacDonald, *et al.*, 1971).

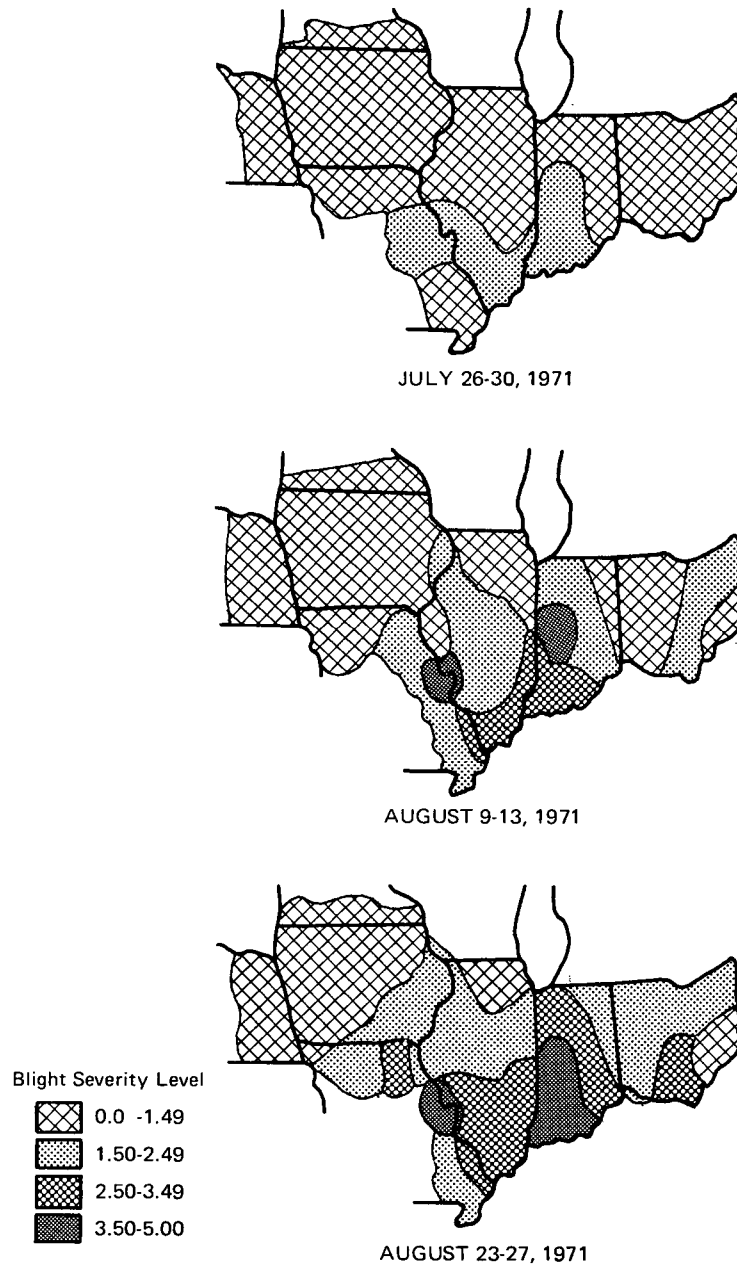


Figure I-6. Blight Severity of Texas Male Sterile Cytoplasm Corn from July 26 Through August 27, 1971. [Source: MacDonald, *et al.*, 1971.]

ERTS-1: A New Satellite Views the Earth

The ERTS program is the first satellite program to be devoted exclusively to a study of the Earth and its resources. In late July, NASA launched the first of the ERTS program satellites into a sun-synchronous, polar orbit some 560 miles above the Earth. As the Earth rotates beneath it, several instruments scan and record data which are then used to create images of forests, oceans, croplands, deserts and other areas.

ERTS-1 carries two basic types of sensors—RBV's for Return Beam Vidicon cameras, and MSS for multispectral scanners. The RCA-developed RBV system is essentially three channels of high quality television, about ten times the detail of home or weather satellite television. The MSS, developed by Hughes Aircraft, scans the Earth using oscillating mirrors and detectors in four energy bands.

Data collected by the RBV and MSS systems is transmitted by microwave to the Goddard Space Flight Center in Maryland, where images are automatically corrected and converted to 70-millimeter black and white positives. All seven color bands—three RBV's and four MSS—are recorded on separate frames, and some scenes are made into color composite images using "false color" techniques.

Every 18 days the system, whose output is about the same as that of three continuous commercial television channels, images most of the world. An estimate of the amount of data that will be available after only one year of operation includes:

- 70,000 spacecraft observations (scenes) with up to 100 distinct data products/observations;
- Over 500,000 different photographic products;
- As many as 40,000 different digital tapes; and
- Up to 40 different observations for any geographic area (Viglione, 1972).

Goddard also prepares a computer index of all the photographs made in each cycle as well as samples of thousands of them on 16-millimeter microfilm. Some 300 NASA-funded research groups in countries throughout the world secure selected pictures for a wide variety of developmental purposes directly from Goddard (See Attachment II).

While it is still too soon to evaluate the impact of the ERTS program, much progress has been made in machine processing of ERTS imagery. The University of California, for example, has shown that computer processing can correctly classify over 95 percent of an MSS image containing six categories of agricultural information (Colwell, September 1972).

For the first time, remote sensing data is easily available to the general public through the Sioux Falls Data Center of the Department of Interior. This Center was designed to serve all persons and groups not qualified to receive imagery directly from NASA. Additionally, the National Oceanic and Atmospheric Administration operates an Earth Resources Data Center with special emphasis placed on working with meteorologists, hydrologists, oceanographers, and the U. S. Department of Agriculture.

Conclusion

Remote sensing technology is unique in many ways. Previously untapped secrets about our planet are being regularly revealed through the systematic processing and dissemination of enormous quantities of specialized visual information. While the large-scale processing requirements for a single satellite—ERTS-1—are staggering, other programs will call into being even more sophisticated equipment. Skylab, due to become operational in 1973, will employ astronauts to select and calibrate sensors, interpret measurements before sending data to the Earth and detect unforeseen events. Skylab will also provide broader spectral coverage with thirteen multispectral channels, as compared to the four-band ERTS scanner. As Skylab and subsequent satellite-based resource survey programs become operational, the techniques for machine processing and interpretation of imagery will become more and more important.

ATTACHMENT II ERTS-1 EXPERIMENTS

43

Electronic imagery has played a key role in the space program through applications such as computer-aided design, quality assurance, training simulators, pre-launch checkout and mission control, and planetary exploration. In the last application, for instance, visual displays of telemetered imagery were crucial in mapping the Moon and Mars. However, the most significant imagery may be obtained from earth-oriented spacecraft. While electronically reproduced weather satellite pictures are a basic input to many weathermen around the world, the launch, in July 1972, of NASA's first Earth Resources Technology Satellite (ERTS-1) provided a whole new dimension in the continuing exploration of Earth. ERTS-1 is now transmitting, on a repetitive basis, synoptic views of the Earth in a data form compatible with electronic display devices and computer processing equipment. The following list indicates some of the more than 300 applications being developed, with NASA funding, using this new data source. The list was compiled to illustrate the range of social, economic, and technical applications that are being pursued through machine-processed visual displays.

AGRICULTURE/FORESTRY

Wind Erosion of Soils

Crop Identification and Acreage Measurement Using ERTS Imagery

Reflectance of Vegetation, Soil and Water

Inventory of Forest and Range-Land Resources

Range Quality during Normal Grazing Season

Timber Resource Information System in the Pacific Northwest

Changes in Continental Migratory Bird Habitat

Proposal to Develop a Multi-Stage Forest Sampling Inventory System

Uniform Mapping and Monitoring of Earth Resources

Use of Satellite Imagery for Wildland Resource Evaluation

Use of ERTS-1 Mapping and Managing Soil and Range in Nebraska

Using ERTS Data from the Wabash River Basin

Evaluation and Comparison of ERTS Data over Sites in Europe, North America and South America

Remote Sensing in Controlling Pink Bollworm in Cotton

Agricultural Practices in the Mississippi Delta

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Natural Resources Inventory

Susitno Valley—Agricultural Lands Classifying for Rapid Development

Evaluation of Satellite Data as a Source of Useful Information for Agriculture/Forestry

Regional Agricultural Surveys Using ERTS

Identification of Soils and Soil Conditions

Use of ERTS in Great Plains Corridor

Application of Space Imagery to Agriculture

GEOGRAPHY/DEMOGRAPHY/CARTOGRAPHY

Application of ERTS Imagery to Thematic Mapping

ERTS Imagery in Polar Regions

ERTS Return Beam Vidicon Camera System and Multispectral Scanner Imagery for Photomapping

Census Cities Experiment

Investigations Utilizing Data from ERTS . . . Urban and Regional Planning

Investigation Using Data from ERTS

ERTS Study of Recreational Land Use and Open Space

Land Use of Northern Megalopolis

Feasibility of Locating Large Archeological Village Sites by Remote Sensing

Investigate the Geographic Application of ERTS-1 Imagery

Compile Two Photo-Maps of the State of Nevada

Evaluation of Satellite-Sensed Information

In Situ Spectroradiometric Calibration of ERTS and EREP Imagery

Culture and Ecology

Cartographic Evaluation of ERTS

Cultural Interpretation and Map Revision from ERTS

Investigation of Satellite Imagery for Regional Planning

Evaluation of ERTS Imagery for Cartographic Application

HYDROLOGY

Use of Space Data in Watershed Hydrology

Evaluation of ERTS Data for Hydrological Uses

Sediment Pattern Correlations with In-Flow and Tidal Action

Arctic and Subarctic Environment Analysis Utilizing ERTS

Reservoir Management and Operations Functions

Applications of ERTS Data Collection System in Arizona Regional Ecological Test Site

Evaluation of Dynamic Hydrological Conditions Using Time Lapse Processing of ERTS-1 Data

Test Use of Dynamic Basic Characteristics Extracted from ERTS Data

Evaluate ERTS Imagery for Mapping and Detection of Change of Snow Cover on Land and on Glaciers

Near Real-Time Water Resources Data for River Basin

Dynamics of Distribution and Density of Phreatophytes and Other Arid Land Plants

Application of ERTS for Snow Cover Survey

Snow Break-up Characteristics

ERTS Program for International Field Year for Great Lakes

Investigation Using Data in Alabama from ERTS

Dynamics of Playa Lakes in the Texas High Plains

Environmental Study of ERTS-1 Imagery—Lake Champlain Basin

. . . ERTS in the Preparation of Hydrological Atlases of Arid Lands Watersheds

Performance of ERTS System in a Total System Context

Dynamics of Suspended Sediment Plumes in Lake Ontario

OCEANOGRAPHY

Evaluation of ERTS for Oceanographic Uses

Ocean Eddies in the Lesser Antilles Using ERTS Data

Remote Sensing of Ocean Currents

Investigation Using Data from ERTS and SKYLAB

Near-Shore Coastal Processes

Accurate Prediction of Ocean Currents

Studies of Inner Shelf and Coastal Sedimentation

Sources and Dispersal Patterns of Suspended Particulate Matter

Estuarine and Coastal Water Dynamics Controlling Sediment Movement and Plume Development

ERTS for Surveying Antarctic Iceberg Resources

ERTS for Sea Ice Survey

To Improve Menhaden Fishery Prediction

Coastal Ground Truth Data for Correlation with ERTS-1 Imagery

. . . Measurement of Water Depth

Estuarine and Coastal Oceanographic Remote Sensing Research

The Circulation of Prince William Sound

Dynamics of Plankton Populations

Survey of Alaska Environment Centralized Facilities and Services

Sea Ice and Surface Water Circulation, Alaskan Continental Shelf

Marine Environment of the Northern Gulf of California

TECHNIQUES DEVELOPMENT

ERTS Information System Development for Potomac River Basin Natural Resource Management

Use of ERTS in Chesapeake Bay Region

Digital Correction Techniques

All-Digital Precision Processing of ERTS Images

Land Use Management in Minnesota

Ocean Water Assessment from ERTS-1 Return Beam Vidicon Camera and Multispectral Scanner Imagery

Image Data Compression Technique

Attenuation of Multisensor Data from Selected Terrain Features

Image Enhancement and Advanced Information Extraction Techniques

A Kansas Environmental and Resources Study: A Great Plains Model

Utilization of ERTS Data as an Education and Research Tool

Land Use Planning on the Mississippi Gulf Coast

Data Collection Platform Interface Electronics

**ATTACHMENT III
TECH BRIEF EXHIBIT**

51

Tech Brief Number	Tech Brief Title
63-10227	Electromechanically Operated Camera Shutter Provides Uniform Exposure
63-10311	Oil-Smeared Models Aid Wind Tunnel Measurements
64-10209	Raster Linearity of Video Cameras Calibrated with Precision Tester
65-10030	Library of Documents Compressed into Lap-Held Display Kit
65-10171	Fresnel Zone Plate Forms Images at Wavelengths Below 1000 Angstroms
65-10200	Density Trace Made with Computer Printout
65-10283	Electron-Beam Deflection Controlled by Digital Signals
66-10016	Single Projector Accommodates Slides of Different Size and Format
66-10062	Fortran Program Flowchart Is Automatically Produced
66-10086	Screen of Cylindrical Lenses Produces Stereoscopic Television Pictures
66-10095	Ultraviolet Photographic Pyrometer Used in Rocket Exhaust Analysis
66-10112	New Television Camera Eliminates Vidicon Tube
66-10200	Apparatus Presents Visual Display of Semiconductor Surface Characteristics
66-10223	Multicolor Stroboscope Pinpoints Resonances in Vibrating Components
66-10307	Commercial Film Produces Positive X-Ray Photo in Ten Seconds
66-10361	New Computer System Simplifies Programming of Mathematical Equations
66-10362	Automated Drafting System Uses Computer Techniques
66-10363	Infrared Television Used to Detect Hydrogen Fires
66-10379	Human Transfer Functions Used to Predict System Performance Parameters
66-10494	Optical Monitor Panel Provides Flexible Test Panel Configurations
66-10548	Security Warning System Monitors up to Fifteen Remote Areas Simultaneously
66-10590	Study Made of Application of Stereoscopic Display System to Analog Computer Simulation
66-10602	Exposure Value (EV) System Expanded to Include Filter Factors and Transmittance
66-10638	Twin Helix System Produces Fast Scan in Infrared Detector
66-10668	Photographic Method Measures Particle Size and Velocity in Fluid Stream
67-10005	Digital Computer Processing of X-Ray Photos
67-10008	Polaroid Film Helps Locate Objects in Inaccessible Areas Quickly
67-10139	Recording and Time Expansion Technique for High-Speed, Single-Shot Transient Video Signal
67-10152	Means for Improving Apparent Resolution of Television
67-10162	Closed Circuit TV System Monitors Welding Operations
67-10175	Numerical Data Frame Readout System Used in Testing Telemetry Systems
67-10222	Subroutines GEORGE and DRASTC Simplify Operation of Automatic Digital Plotter
67-10240	Vis-A-Plan (Visualize A Plan) Management Technique Provides Performance-Time Scale
67-10241	A Simplified PERT System
67-10248	Rectilinear Display Gives Acceleration Load Factor and Velocity Information
67-10249	Computer Program Samples Digital Data for CRT Display

ATTACHMENT III (CONTINUED)

Tech Brief Number	Tech Brief Title
67-10269	Oscilloscope Used as X-Y Plotter or Two-Dimensional Analyzer
67-10297	Fresnel Diffraction Plates Are Simple and Inexpensive
67-10342	Simplified Technique Demonstrates Magnetic Domain Switching
67-10363	System Automatically Provides Dynamic Launch Decision Criteria
67-10431	Camera Lens Adapter Magnifies Image
67-10492	Computer Program Reduces and Provides Profile Plot of Surface Plate Calibration Data
67-10505	Thin Film Thermal Detector
67-10508	Glancing Incidence Telescope for Far Ultraviolet and Soft X-Rays
67-10515	Video Synchronization Processor Overcomes Poor Signal-to-Noise Ratio
67-10568	Graphic Visualization of Program Performance Aids Management Review
67-10609	Gimbaled-Mirror Scanning System Capable of Spiral Pattern
67-10630	Computer Program for Video Data Processing System (VDPS)
67-10654	X-Y Plotter Adapter Developed for SDS-930 Computer
67-10662	Phase Plane Displays Detect Incipient Failure in Servo System Testing
67-10676	Scan Rate Converter for Tape Recording and Playback of TV Pictures
68-10021	Optical System Facilitates Inspection of Printed Circuit Boards
68-10028	Electronic "Aperture Control" Devised for Solid State Imaging System
68-10056	Luminescent Screen Composition for Cathode Ray Tubes
68-10069	Principles of Optical-Data Processing Techniques
68-10121	Circuit Enhances Vertical Resolution in Raster Scanning Systems
68-10131	Automated Patient Monitoring System
68-10149	System Remotely Inspects, Measures, and Records Internal Irregularities in Piping
68-10155	Hydra I Data Display System
68-10259	Fluorescent Particles Enable Visualization of Gas Flow
68-10271	Preparation of Silver-Activated Zinc Sulfide Thin Films
68-10282	High-Speed Camera Synchronization
68-10296	Computer Graphics Data Conditioning
68-10314	Color-Televised Medical Microscopy
68-10335	Computer Program Analyzes and Designs Supersonic Wing-Body Combinations
68-10336	Fully Automatic Telemetry Data Processor
68-10343	X-Ray Film Holder Permits Single Continuous Picture of Tubing Joint
68-10347	Improvement in Recording and Reading Holograms
68-10350	Fluidic-Thermochromic Display Device
68-10363	Improved Radiographic Image Amplifier Panel
68-10402	System for Measuring Spatial Distribution of Ejected Droplets, A Concept
68-10434	Selective Video Blanking Technique
69-10066	Fractography Can Be Used to Analyze Failure Modes in Polytetrafluoroethylene
69-10073	Electronic Visualization of Gas Bearing Behavior
69-10075	Selective Vignetting of Type 1 X-Ray Telescopes
69-10113	Surface Temperature Mapping with Infrared Photographic Pyrometry

ATTACHMENT III (CONTINUED)

Tech Brief Number	Tech Brief Title
69-10122	Fluorescent Photography of Spray Droplets Using a Laser Light Source
69-10139	VICAR-Digital Image Processing System
69-10224	Two Devices for Analysis of Nystagmus
69-10226	Camera Mount for Close-Up Stereo Photographs
69-10243	Time-Shared Cathode Ray Tube
69-10247	Simplified System Displays Complex Curves Corresponding to Input Data
69-10325	Combination Ranging System and Mapping Radar
69-10394	Visual Task Analysis (VISTA)
69-10465	Technique for Pinpointing Submicron Particles in the Electron Microprobe
69-10537	Improved Camera for Better X-Ray Powder Photographs
69-10594	Airborne Fraunhofer Line Discriminator
69-10662	Two-Color Holography
69-10663	Fine-Line Sensitivity for Holographic Interferograms
69-10676	Technique for Improving Solid State Mosaic Images
69-10700	Long Range Holographic Contour Mapping Concept
69-10748	System Converts Slow-Scan to Standard Fast-Scan TV Signals
70-10002	Device for Printing Alphanumeric Listings and Digital Data Plots
70-10030	Contourograph Display System for Monitoring Electrocardiograms
70-10123	Holographic Stress Analysis
70-10184	PERT "C"
70-10209	Television Camera as a Scientific Instrument
70-10229	Electro-Optical Time Marker for High-Speed Cameras
70-10230	Improved Antenna Pattern Recorder Provides Visual Display of RF Power
70-10268	The Effect of Object Motion in Fraunhofer Holography with Application to Velocity Measurements
70-10271	Finite Fringe Hologram
70-10290	Slide Checkout Console
70-10311	Computerized Polar Plots by a Cathode Ray Tube/Grid Overlay Method
70-10360	Multispectral Facsimile Reproducer
70-10365	Reducing Streak Film Data Via Electronic Cross Correlator
70-10426	Multipass Holographic Interferometer Improves Image Resolution
70-10440	Luminescent Screen Composition and Apparatus
70-10447	Biomedical Sensing and Display Concept Improves Brain Wave Monitoring
70-10454	Multilayer Screen Gives Cathode Ray Tube High Contrast
70-10464	Color Television System Using Single Gun Color Cathode Ray Tube
70-10472	Ambient-Light-Absorbing Screen for Front Projection
70-10476	Visual Display Panel Functions as Computer Input/Output Device
70-10484	Concept for High Speed Computer Printer
70-10515	Fault Detection Monitor Circuit Provides "Self-Heal Capability" in Electronic Modules: A Concept
70-10571	Electron Fractography Used to Examine Nickel-Base Alloys

ATTACHMENT III (CONTINUED)

Tech Brief Number	Tech Brief Title
70-10654	Holographic Analysis of Thin Films
70-10660	Man-Machine Interactive System Simplified Computer-Aided Circuit Design
70-10705	Digital Simulation Program Improved
71-10016	Electromagnetic Simulation of Microwave Backscatter from the Ocean Surface: A Feasibility Study
71-10021	Study of Second Breakdown in Power Transistors Using Infrared Techniques
71-10022	Design and Development of a Fast Scan Infrared Detection and Measurement Instrument
71-10065	Multiple Shutters for a Stereoscopic Camera
71-10068	Kaleidoscopic Light Feedback for Television Systems
71-10108	Fiscal Output Data Produces Versatile Graphic-Numeric Charts
71-10141	New Filter Technique Improves Home Television Reception
71-10145	Vibration Detection Using Lasers
71-10223	Solar Cell Power Scanner
71-10226	Multilayered Printed Circuit Boards Inspected by X-Ray Laminography
71-10263	Man-Machine Communication: A Transparent Switchboard for Computers
71-10299	Data Sampling System for Monitor and Control Station

ATTACHMENT IV

Summaries of Technology Transfer Reports Involving
NASA-Generated Visual Display Systems Technology

ATTACHMENT IV
SUMMARIES OF TECHNOLOGY TRANSFER REPORTS INVOLVING
NASA-GENERATED VISUAL DISPLAY SYSTEMS TECHNOLOGY

NASA CONTRIBUTIONS	TRANSFER STAGES							
	1		2		3		4	
	Cont.	Term.*	Cont.	Term.	Cont.	Term.	Cont.	Term.
● Automated Patient Monitoring System		16960**					62401	
● Computer Display System							76502	
● ECG Monitoring With Contourograph Display					43946			
					47118			
● Infrared Scanner for Nondestructive Testing					57574		70001	
● NASTRAN***								
● Optical-Data Processing Handbook					17080			
					21368			
					35410			
					49588			
					59960			
● PERT Vertical Chart Display		35868						
● Phototransistor Mosaic					76501			
● Single Gun Color CRT		57800	58036			57882		
			58896					
● Surface Temperature Mapping With IR Photo Pyrometry			42606					
● The General Electric Computed Color TV Display			64102		64101			
● Universal Control and Display Console				63801				
● Videofile							66201	
● Vis-a-Plan Management Technique				23570	5054	28862		
					5067			
● Visual Display Panel and Computer Input/Output Device		58894	55508					
			57912					
● Weather Satellite Image Display					78001		431	
					78002			

* The action status, continuing or terminated, of transfer cases at the time DRI-TRIS contacted users. Cases are classed as terminated when (a) no further adaptation or adoption is contemplated, (b) a better technical alternative has been found, or (c) continued transfer activity is not economically feasible.

** Numbers in columns refer to TRIS case numbers.

*** This Technology Transfer Example Summary is based on a report by Computer Sciences Corporation, entitled *NASTRAN Benefits Analysis*. No TRIS cases are involved.

AUTOMATED PATIENT MONITORING SYSTEM TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The Boeing Company, under contract to NASA's Marshall Space Flight Center, developed a radio-linked patient monitoring system that is capable of collecting several channels of physiological data from as many as 64 hospital patients and transmitting the data to a central control station. The information is transmitted in digital form and is directly processed by a computer. Battery-operated patient units consist of small strap-on electronics packages weighing less than one pound, enabling their use on ambulatory as well as bedridden patients. A typical unit contains four EKG electrodes, two thermistors for temperature measurement, and a strain gage to monitor blood pressure. A unique characteristic of the Boeing system is its "interrogation" mode of data transmission. Using a single frequency for the central station and patient units, the system allows input of data from each patient only upon interrogation from the central station, which occurs at regular intervals, allowing a two-second transmission from each patient in turn. In the "single patient" mode, any patient can be continuously monitored by setting a selector switch in the central station. The Boeing system was announced by NASA in a 1968 Tech Brief.

Peter Petroff, who had been associated with Marshall's contract monitoring duties, left NASA in 1969 to form his own company, Care Electronics in Huntsville, Alabama (62401), which is producing a modified version of the monitoring system. Based partly on the Boeing design and significantly on telemetry technology from the NIMBUS program, Petroff's system continuously monitors EKG, blood pressure, and temperature of four patients using a PCM-FM telemetry method which provides signals free of static and other interference. His system interfaces directly with computers. The interference-free transmission allows insertion of control limits for alarm systems, with the assurance that an alarm is triggered only by a physiological emergency. First-year sales of the system were \$980,000; second-year sales projections of \$2.9 million were realized; and four regional sales offices were opened during 1971. Petroff estimates that if it had been necessary to duplicate the NIMBUS technology, the cost would have been approximately \$500,000 to \$600,000. He also found that the performance and construction specifications for the Boeing system were excessively expensive for the existing market. The very high reliability levels in the NASA specifications (e.g., 98 percent) cost about three times more to achieve than a lower level (93 percent) acceptable for this commercial product.

Honeywell, Incorporated in Denver, Colorado (16960) has had a patient monitoring system on the market for several years which provides a continuous, permanent EKG and blood pressure record. Research engineers at Honeywell reviewed the TSP for potential modifications of the company's product. Although the NASA technology offered a new approach to biotelemetry, the engineers concluded that major product changes would not be cost effective. They have no further interest in the TSP.

Control Numbers

Tech Brief Number: 68-10131
NASA Center: Marshall Space Flight Center
TRIS Case Numbers: 16960, 62401
TEF Number: 116
Date of Latest Information Used: March 30, 1972

COMPUTER DISPLAY SYSTEM TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In 1964, functional requirements anticipated for the Saturn V pre-launch checkout operations called for unique computer input/output capabilities. Provisions were included for intermixing and overlaying closed circuit TV data and computer-generated lines/characters at the display face; automatic and rapid accessing (by the CCTV subsystem) of a large 35mm checkout data slide bank; and a multiterminal system configuration. These capabilities were not available in an integrated way in existing display systems at the time.

Sanders Associates, Incorporated (76502), in 1965, received a NASA contract to develop the Saturn V Operational Display System for the large-scale digital systems (RCA 110A) at each of seven installations at Kennedy Space Center and Marshall Space Flight Center. During the two-year development phase, an input/output console was designed to provide (1) a high-capacity logical interface between the RCA 110A and the display; and (2) a unique dual-mode cathode ray tube deflection system. At the time, the latter represented a significant advancement in CRT state-of-the-art in that it combined the wide bandwidth, low power requirement of line and character generation with the narrow bandwidth, high power essential to precise registration (at the scope face) of intermixed CCTV and computer-generated data. Critical to these requirements was a beam deflection yoke specifically designed for this application.

After the design/development phase was completed, the fifty engineers and technicians of the Data Display Systems Department engaged in the Saturn V effort were reassigned to an internally funded project to develop a commercial equivalent of the NASA system. Utilizing the Saturn V system as a prototype, redesign was undertaken to (1) provide operational compatibility with a broad range of commercially available digital processing systems; (2) decrease the burden imposed on the computer by line and symbol generation; (3) simplify the computer-display interface; (4) provide "centralized" character and line generation; and (5) broaden the variety of data control and entry, indicator, and recording devices available at the display console.

As a result of this effort, a display processor, display generator, and series of consoles were developed during 1966-68 and subsequently marketed. Sanders' ADDS/900 System series, for example, is recognized as unequalled in display capacity and flexibility. Twenty-eight of these systems have since been delivered to a broad range of federal and commercial organizations, both domestic and foreign, with applications in computer-aided design, flight simulation/pilot training (DC-10), real-time flight test monitoring and air traffic control. The base price for an ADDS/900 System is approximately \$70,000.

McDonnell-Douglas used one of Sanders' display systems in flight testing the new DC-10 in 1970. For this application, a \$3.5 million automated data handling system was provided by Xerox Data Systems, which included a \$700,000 Sanders display system as part of the package. One benefit of the automated data handling was a reduction in total flight test time from a projected 2,000 hours to 1,250 hours.

Using the same technology, Sanders developed another display system called CLINI-CALL, a medical data management system. Hospital data management problems are increasing as a result of more admissions, shorter stay times per patient, more laboratory instruments and tests, and more inputs to diagnosis. The Sanders system stores, retrieves, routes, and checks such data; it provides patient medical

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histories and current medical records, statistical summaries, and legal records; it also schedules medical tests and keeps inventories of supplies and bed availability. Remote terminals in key locations allow easy access to the computer by authorized personnel. The Mayo Clinic installed CLINI-CALL displays in 1971 to manage accounting and admissions data. A seven-year backlog in these records was brought up-to-date in thirty days. Other hospitals installing the system include Kaiser Memorial Hospital in San Francisco and Walter Reed Hospital in Washington, D. C.

Sanders' management credits the Saturn V Operational Display System project with significant advancement in the state-of-the-art; in providing for the development of an unequalled, in-house (Sanders') capability in display system design; and in providing a functional engineering prototype from which a commercial system of expanded capability, efficiency and lower cost emerged.

This example traces the manner in which a stringent aerospace requirement accelerated the development of industrial technological expertise; and, subsequently, how an internal, lateral transfer of such expertise resulted in successful commercial product activities.

Control Numbers

Tech Brief Number: None
NASA Centers: Kennedy Space Center; Marshall
Space Flight Center
TRIS Case Number: 76502
TEF Number: 99
Date of Latest Information Used: February 16, 1972

ECG MONITORING WITH CONTOUROGRAPH DISPLAY TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A new biomedical display system developed for the NASA Manned Spacecraft Center by Technology, Incorporated was the subject of Tech Brief 70-10030. The system was devised for real-time presentation of an electrocardiogram (ECG) in a three-dimensional form. The ECG is displayed as a contourogram on the cathode ray tube of a variable-persistence oscilloscope. Successive ECG cycles are stacked below their predecessors, which achieves the three-dimensional effect; a major change in the ECG signal markedly alters the contourogram pattern. The three-dimensional effect is accentuated by dynamically modulating trace intensity so that ECG peaks are brighter than the baseline.

A research associate in the Department of Logopedics at Wichita State University in Wichita, Kansas (47118) has constructed a demonstration model of the contourograph display system. It is now available for use whenever a pertinent research problem arises.

A professor of Veterinary Medicine and Bioengineering at the University of Missouri in Columbia (43946) has built a laboratory model of the display for his research on post-surgical erythmia in animals. A means of recording data so that every ECG complex did not have to be studied in real-time was needed. The professor acquired the NASA TSP and adapted the concept for operation with magnetic tape and a computer interface to permit digitizing and storage of the data. The adaptation also reduced equipment requirements.

Control Numbers

Tech Brief Number: 70-10030
NASA Center: Manned Spacecraft Center
TRIS Case Numbers: 43946, 47118
TEF Number: 390
Date of Latest Information Used: September 30, 1971

INFRARED SCANNER FOR NONDESTRUCTIVE TESTING TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In the mid-1960's, Raytheon Company developed an operational infrared scanning microscope system for automated nondestructive testing of electronic components, under contract to NASA's Marshall Space Flight Center. The unit, which Raytheon called the Compare System, included the results of previous research funded in-house and by the Defense Department. The Compare System incorporated computer processing and storage capabilities with high sensitivity, fast detector response, and good resolution on the real-time cathode ray tube display. Thermal infrared profiles for semiconductor chips, transistors, and integrated circuits can be measured and plotted with the Compare System. An analysis of each profile yields valuable information on electrical and physical properties for design improvement and quality control of the electronic component tested.

Several Raytheon engineers who had helped develop the technology founded Dynarad, Incorporated in Norwood, Massachusetts (70001) in 1968. Dynarad then purchased all of Raytheon's rights related to infrared nondestructive testing, together with Raytheon's prototype model of the Compare System. With in-house funds, Dynarad miniaturized the system to make it portable, redesigned the scanning device, incorporated a variety of detectors to provide different infrared channels for different applications, and made several other refinements on the Compare System design. As a result of these developments, Dynarad introduced two products on the commercial market in 1971: the Fast Scan Infrared Camera and the Fast Scan Infrared Microscope. In the first year, 33 Fast Scan Infrared Cameras were sold at prices ranging from \$18,900 to \$26,700. The cameras are being used for nondestructive testing of electronic circuits, void detection in honeycomb construction, gas laser research, and automobile tire design testing. They are being evaluated by potential customers for computer-automated, assembly line quality control for automobile radiators and tires.

The NASA development contract with Raytheon included a test program to study the potentially destructive phenomenon of second breakdown in bipolar power transistors. In 1971, NASA published Tech Brief 71-10022 which described the fast scan infrared detection and measurement instrument and Tech Brief 71-10021 which described the test program results from using the instrument.

Perkin-Elmer Corporation in Pomona, California (57574) used the TSP for Tech Brief 71-10021 to establish test procedures for a power transistor component used in several of the company's mass spectrometer products. As a result of the tests, the transistor was found to be prone to second breakdown and was subsequently replaced in the products. By eliminating this cause for equipment failure, Perkin-Elmer is saving time, money and reputation. The need and technique for testing power transistors for second breakdown is now a part of the company's engineering expertise and will probably be used in the future.

Control Numbers

Tech Brief Numbers: 71-10021, 71-10022

NASA Center: Marshall Space Flight Center

TRIS Case Numbers: 57574, 70001

TEF Number: 398

Date of Latest Information Used: January 18, 1972

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NASTRAN TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The NASA Structural Analysis Program (NASTRAN) is a general purpose, digital computer program designed to analyze static and dynamic behavior of elastic structures and to display a summary of the computed structural behavior with standard computer plotters. The program was, and still is, used by NASA and aerospace companies to design and analyze aircraft fuselages, wings and tail assemblies, space vehicles (Viking and Skylab) and their related launch facilities, and turbine engines.

The wide range of analytic capability built into NASTRAN includes: static structural response to concentrated and distributed loads; thermal expansion and enforced deformation; dynamic structural response to transient loads; steady-state harmonic loads and random excitation; and determination of real and complex eigenvalues for use in vibration analysis, dynamic stability analysis and elastic stability analysis. The program is highly user-oriented through an easy data input format, error message vocabulary, and annotated, modular output format. The output plotting may be selected from a variety of structural and curve plotting options. NASTRAN can handle structural problems of virtually unlimited size.

Between 1965 and 1970, Goddard Space Flight Center developed the program through a combination of in-house and contracted research for approximately \$3,000,000. Five Special Publications resulted, which describe different aspects of NASTRAN: SP-260, SP-221, SP-222, SP-223, and SP-224. The first document, SP-260, is a general summary of NASTRAN functions and capabilities; the other four describe the theory, use, programming, and sample problems related to it. After Goddard programmers and engineers completed NASTRAN's development, it was released to public users in November 1970. The program, as is the case with most NASA computer programs, is being disseminated at cost by the Computer Software Management and Information Center (COSMIC) at the University of Georgia, under contract to NASA. A set of NASTRAN tapes and documentation can be purchased from COSMIC for an average cost of \$1,700, depending on the options required by the user. The NASTRAN Systems Management Office (NSMO) was established at NASA's Langley Research Center to provide users with essentially free program maintenance services. NSMO operates on an annual budget of about \$400,000.

An extensive analysis of NASTRAN benefits was recently conducted by Computer Sciences Corporation (CSC) under contract to Goddard. A sample of 205 NASTRAN users was surveyed by mail questionnaires, telephone interviews and personal interviews. The initial mailing resulted in 152 responses, which identified 186 current applications and an additional 55 more in the planning stage. This Transfer Example Summary is based on CSC's final report, entitled *NASTRAN Benefits Analysis*.

For most NASTRAN users, the primary benefit has been a substantial reduction in real operating costs and, therefore, a great increase in productivity. Based on the CSC study, five important factors contributing to this benefit were: analyses were accomplished which could not have been done without NASTRAN; more complete and accurate results were attained; development time was shortened; communication between engineers and programmers was improved; and cost of analysis was reduced. Ford Motor Company, for example, is saving an estimated \$12,000,000 annually by using NASTRAN for quality assurance analysis of automobile frames. A nonaerospace company has used it to save an estimated \$5,000,000 of the costs for new product development. A commercial service bureau has an annual revenue of \$240,000 from applications of the NASTRAN program. Nonaerospace applications for

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industrial and service bureau users included examples such as large buildings, machinery structures, high-speed railroad tracks, trussed structures, electronic products, shell structures and vessel support structures. Two-thirds of the 186 applications would not have been attempted without NASTRAN.

Based on the survey data, the following benefits were summarized in the CSC report:

- NASTRAN is considered to be vital to the structural analysis community. Two-thirds of current NASTRAN applications would not have been attempted without it.
- Users have spent an estimated \$1,732,000 to apply and improve NASTRAN.
- Total annual savings estimated by all respondents of the CSC survey exceeded \$14.5 million; and NASTRAN was contributing to new product developments valued at more than \$5.6 million.
- Services based on NASTRAN are generating more than \$240,000 in new business annually.
- 667 persons, primarily engineers, were using NASTRAN at the time the study was undertaken.

These figures compare favorably with NASA's development and operating costs.

Control Numbers

Tech Brief Number: None

NASA Centers: Goddard Space Flight Center; Langley Research Center

TRIS Case Number: None

TEF Number: 410

Date of Latest Information Used: February 15, 1972

OPTICAL-DATA PROCESSING HANDBOOK TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Despite the existence of abundant literature on all aspects of optical-data processing, persons with only a general technical background may experience great difficulty in becoming familiar with the field because most of the literature is written at highly advanced levels. In order to fill a recognized need for an introductory exposition of the basic principles of optical-data processing, including optics, photography, electronics, holography, and other matters, A. R. Shulman of NASA's Goddard Space Flight Center compiled a self-teaching text which gives readers an overview of the subject. Mathematical discussions are presented; however, a basic understanding can be gained without reliance on those sections. In March 1968, NASA announced the handbook's availability through Tech Brief 68-10069, "Principles of Optical-Data Processing Techniques." To date, NASA has received over 1,000 requests for the TSP.

Engineers with Grumman Aerospace Corporation in Bethpage, New York (35410) refer to the TSP on a daily basis for information relevant to their development of commercial and aerospace optical-data processing systems. A Grumman engineer reported that the NASA document has provided information which was quite important in solving development problems.

The TSP has been widely circulated at the Sperry Rand Research Center in Sudbury, Massachusetts (21368). Several researchers regularly use the document for reference purposes and, in one instance, saved over \$5,000 of the developmental costs for a computer-linked radar product.

A graduate student in physics at Cornell University in Ithaca, New York (17080) realized a significant time savings in his doctoral research by using the TSP to set up his experiments on metal defects. He used one of the optical-data processing techniques in conjunction with a computer to record and analyze the laboratory data.

Technology, Incorporated in Dayton, Ohio (49588) applied information from the TSP to an image enhancement project it conducted for Goddard. The project produced both a theoretical and a hardware model for "desmearing" the motion-degraded pictures from Earth Resources Technology Satellites (ERTS). Information from the TSP was used in converting the theoretical model to operational equipment that can eliminate motion-caused blurs in pictures.

A research associate in psychology at Loyola University in Chicago, Illinois (59960) used practical information about Fourier transforms from the TSP in designing experimental equipment for an NSF-funded project in psychophysiology. The equipment is being used to investigate human visual perception. More than 50 hours of research time were saved by using the TSP.

Control Numbers

Tech Brief Number: 68-10069
NASA Center: Goddard Space Flight Center
TRIS Case Numbers: 17080, 21368, 35410, 49588, 59960
TEF Number: 24
Date of Latest Information Used: March 30, 1972

PERT VERTICAL CHART DISPLAY TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Rapid review of PERT computer printouts is commonly handicapped by the nongraphic format of the information. The problem can be lessened by using a new format developed at the Aerojet-General Corporation, under contract to the Space Nuclear Systems Office (formerly the Space Nuclear Propulsion Office). The method, called PERTREE and described in Tech Brief 67-10568, displays essential status elements of a PERT system in a highly graphic, vertical flow display. By orienting the summarized network in a vertical display, it is possible to combine the benefits of "waterfall" schedule sequences with the PERT-generated status data.

The director of systems and data processing for the Wisconsin Tuberculosis and Respiratory Disease Association is adapting PERTREE (and PERT) to develop a systems approach to public health problems (35868). This approach is necessary to process the enormous amount of data which must be organized to attain sequencing of report production, experiments, and other management tasks relevant to solving a complex problem. Other Wisconsin public health agencies and the National Tuberculosis and Respiratory Disease Association are actively interested in his work, which is currently in the stage of experimentation with adapted computer methods and display techniques. The system will be implemented when this adaptation work has been completed.

Control Numbers

Tech Brief Number: 67-10568
AEC/NASA Center: Space Nuclear Systems Office
TRIS Case Number: 35868
TEF Number: 370
Date of Latest Information Used: December 22, 1971

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PHOTOTRANSISTOR MOSAIC TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Beginning in 1962, Westinghouse Electric Corporation executed a contract with NASA's Marshall Space Flight Center (MSFC) that culminated in a miniaturized, solid state television camera in which a phototransistor mosaic replaced the vidicon tube as the imaging device. The camera was designed to withstand severe missile firing shock and to minimize size, weight and power requirements. The fragile vidicon tube was eliminated in favor of a mosaic sensor consisting of 2,500 phototransistors for light sensing and image conversion. A digital readout system sequentially scans the phototransistors at 60 frames per second, producing pictures composed of a series of dots rather than lines. NASA announced the invention in a 1966 Tech Brief and obtained a patent in 1969.

Westinghouse has continued its work in the field, including further contract activities for NASA. Nonaerospace applications are being initiated, including use of mosaic arrays for nuclear blast monitoring. In one such use, an underground test was monitored with a cost savings of \$200,000 largely achieved by eliminating post-blast excavation to retrieve the data record.

Another application is being developed by Westinghouse in cooperation with scientists at the Smith-Kettlewell Institute of Visual Sciences, University of the Pacific, San Francisco, California (76501). Eight years ago, Dr. C. C. Collins of the Institute began to experiment with tactile image conversion as a means of restoring visual functions in blind subjects. Dr. Collins' early experimental apparatus used a vidicon camera tube and an orthogonal, logical switching matrix to connect, in sequence, the elements of the vidicon image to corresponding elements of a polarized, solenoid stimulator matrix with small Teflon mechanical stimulators in contact with the skin. The system converted the TV image to a two-dimensional facsimile, which was impressed on the skin by mechanical vibration. Evolution of the research resulted in the design of an electrical stimulus array for impressing the converted image on a patch of abdominal skin and replacing the vidicon camera with a phototransistor array. This system is portable and allows considerable mobility for the blind user. In approximately ten hours, the user can learn to recognize familiar objects, discriminate among individuals, and describe their posture, movements and characteristics.

Dr. Collins first learned of the Westinghouse mosaic in 1971 and, subsequently, acquired several of the units. At present, a 20 x 20 phototransistor array is used; however, experiments with a 1,000-element array are to begin soon. A 4,000-element array also is being developed for the project by Westinghouse. Dr. Collins foresees achievement of an operational system in about three years, with expectations that the 4,000-element array will establish the desired level of resolution.

Control Numbers

Tech Brief Number: 66-10112
NASA Center: Marshall Space Flight Center
TRIS Case Number: 76501
TEF Number: 104
Date of Latest Information Used: February 1, 1972

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SINGLE GUN COLOR CRT • TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A current-sensitive, single gun color cathode ray tube, capable of producing a limited range of colors in a monochromatic black and white closed circuit TV system, was developed by two NASA employees at the Electronics Research Center. Differential color is obtained by varying the current in the electron beam; variation in brightness for a given color is achieved by controlling the duty cycle of the electron beam. The uncomplicated apparatus uses a two primary and single gun system in place of the common three primary and three gun color system, resulting in a reduction of the number of video amplifiers and deflection circuits required to display a color TV picture. The picture tube is less complex, utilizing special phosphors characterized by nonlinearity of response to electron beam excitation to achieve color gradations.

The Magnavox Company in Silver Spring, Maryland (57800) is expanding its operations into cable TV systems. A senior staff engineer requested funds to study biomedical applications of cable TV and collected literature relevant to such a study, including TSP 70-10464 describing the new NASA color system. The development was shifted to another group in the company which plans to use flat panel plasma displays. There are no current plans to use the single gun technology.

Singer-Librascope in Glendale, California (58036) is developing new display systems for the Navy. A laboratory model of the NASA single gun color system will be constructed, and the final outcome of efforts to use the technology should be known by October 1973.

CBS Laboratories in Stamford, Connecticut (58896) is evaluating the invention for adaptation to color movie-making for television. The firm's intention is to develop a high resolution color image on videotape, which can be edited electronically and recorded for storage using laser beams. The process would bypass the photographic film stage and achieve considerable cost savings, as compared with the currently used, three gun color system for television.

GTE Sylvania, Incorporated in Needham Heights, Massachusetts (57882) built an experimental prototype of the driver circuitry and single gun color CRT in order to evaluate its potential for inclusion in a commercial product under development. While the circuitry fit well electronically, the color shift capability of the system was not adequate for the company's purposes. The approach was subsequently abandoned.

Control Numbers

Tech Brief Number: 70-10464
NASA Center: Electronics Research Center
TRIS Case Numbers: 57800, 57882, 58036, 58896
TEF Number: 393
Date of Latest Information Used: October 11, 1972

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SURFACE TEMPERATURE MAPPING WITH IR PHOTO PYROMETRY TECHNOLOGY TRANSFER EXAMPLE SUMMARY

An advanced procedure for measuring and mapping the distribution of temperatures on a heated surface is now available as a result of studies performed at NASA's Lewis Research Center. The method utilizes commercially available equipment to collect, detect, and measure a narrow bandwidth of emitted infrared radiation and convert the data to a topographic style map of the surface. Major components of the system are the heated surface to be measured, which has a reference thermocouple attached; an optical viewpath and camera for recording thermal radiation on IR-sensitive film; a closely controlled film developing unit; a densitometer for measuring and recording the densities of the photographic images and plotting isodensity contours; and a method for converting image densities to temperatures.

The IR photographic pyrometry method is superior to conventional surface thermocouple arrays or radiation pyrometers in several respects. Higher accuracy, a greater range of temperature measurement, and simplification of data handling are achieved. In addition, a thermal photograph can be taken in one second or less, providing a permanent record; and complete temperature distribution data can be obtained without physically contacting or interfering with the heated surface except for the reference thermocouple.

Dr. K. T. Feldman of the University of New Mexico in Albuquerque (42606) intends to use the procedure for a basic research project concerning heated surface temperature distributions, some of which are evaporating water surfaces. The temperatures involved are under 500° F. Although IR detection is more commonly used at higher temperatures, Dr. Feldman is certain that the method will be appropriate for his research. He has submitted a request for an \$8,000 item of Department of Defense surplus equipment with which to set up the IR photographic pyrometry method.

Control Numbers

Tech Brief Number: 69-10113
NASA Center: Lewis Research Center
TRIS Case Number: 42606
TEF Number: 371
Date of Latest Information Used: March 30, 1972

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THE GENERAL ELECTRIC COMPUTED COLOR TV DISPLAY TECHNOLOGY TRANSFER EXAMPLE SUMMARY

General Electric Company, under contracts with NASA's Manned Spacecraft Center (MSC), has conducted extensive development work on a computed color TV display system for simulation of spacecraft docking maneuvers, space shuttle landing, and other space-related applications (64101). The work began in the late 1950's under funding from the Office of Naval Research; it then continued under NASA funding and internal financing at G.E. Used primarily by NASA to date, the scene generator develops simulation displays without using a physical model. A basic scene is created as a computer program; inputs from the operator's control stick and a few dials, such as speed control, produce calculations which then alter the display to reflect the new perspective and position of the operator relative to the basic scene. The calculated view is then presented in real time on a color TV screen by raster scanning. The visual display consists of a textured plane surface, blue sky (if appropriate), point sources of light and various objects. The objects are composed from colored planar segments outlined by straight line segments.

The original unit developed for MSC contained three TV screens for different views of the same scene and the capability to produce up to 240 edges for objects. A more advanced unit, delivered to MSC in October 1971, provides 750 edges (about 200 planar segments) for greater detail and other display improvements resulting from NASA-supported hardware developments. Scenes with up to twenty times greater detail have been made for NASA by generating the scene on TV in slow time, filming the scene with a movie camera, and showing the film at a faster speed.

Using internal funds, General Electric developed the software for several potential applications: highway planning for the New York Highway Department; control tower operator training for the Federal Aviation Administration; aircraft simulators for military and commercial pilot training; ocean and ship simulation for training supertanker captains; and other areas such as animation for TV advertising. Anticipating different uses for any unit purchased, G.E. also has available fast storage equipment (tape or disc file) so that a program for one scene can be replaced rapidly with a program for a different scene. The basic scene generator is now designed in modular form so that fairly standard components may be used to assemble units with various capabilities. Prices range from \$250,000 to \$1,500,000. A significant market for the units does not exist at the present time; however, G.E. anticipates substantial sales in the future.

Professor Peter Kamnitzer, head of the School of Architecture and Urban Planning at U.C.L.A., has developed a cityscape program for urban planning with assistance from G.E. and MSC personnel (64102). Kamnitzer used the scene generator to produce and film a TV cityscape image to simulate various drives through the streets, along with different visual perspectives. He has shown the film at urban planning conferences in the U. S. and Europe. With funding from the Bureau of Highway Safety in the U. S. Department of Transportation, Kamnitzer and a colleague are exploring some applications of the scene generator for highway safety planning. Kamnitzer is presently seeking funds to establish an Urban Simulation Laboratory at U.C.L.A., which would assemble known types of urban models, perform simulations with the models, and develop planning techniques and actual plans from the simulations. If funded, the laboratory is expected to create considerable interest among architects and city planners.

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Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
TRIS Case Numbers: 64101, 64102
TEF Number: 389
Date of Latest Information Used: October 4, 1971

UNIVERSAL CONTROL AND DISPLAY CONSOLE TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In July 1970, General Electric Company's Houston Space Division executed a contract with the Manned Spacecraft Center to define, design, and build the prototype of a Universal Control and Display Console (UCDC) for NASA's Unified Test Equipment (UTE) checkout system (63801). As part of the contractual obligations, G.E. analyzed checkout requirements for a space shuttle and space station, conducted engineering tradeoff studies to determine optimum equipment specifications and configurations, designed and implemented the hardware and software components for the UCDC, tested the system, and provided for its integration with other existing portions of the UTE system. A prototype was developed and delivered to NASA in July 1971.

As part of the tradeoff studies, G.E. ascertained that costs were minimized by using universal, rather than specialized, test equipment and modular construction. Modular universal equipment will decrease equipment inventory and improve manpower utilization, especially if the test equipment is automated to reduce time requirements for preparing and conducting tests. The prototype also promotes efficiency by relying on hardware components as much as possible for performing repetitive functions. The controller serves both as a display processor and as a data acquisition and command processor. Operator interface consists of a variable function plasma display, keyboard entry, and two color CRT's to display special symbols, trend lines, bar graphs, and other application-oriented visual information; tutorial decision trees to guide the operator; and similar images which color code crucial information for rapid comprehension.

The UCDC at MSC thus provides data processing and control to: initiate command signals to the equipment system, select and display parameters of the system status and operating characteristics, perform automatic closed-loop operations, and permit test equipment or monitoring modifications by the operator.

G.E. has published and distributed an advertising brochure for the system, which the company has designated IDAC 560A (Information Display and Control system). The company is adapting the symbology, software, and modular configurations for potential applications in centralized monitoring and control of mass transit systems, oil field production, electric power generation and distribution, shipboard systems, and other complex industrial equipment systems. The basic unit is priced on the order of magnitude of \$100,000. The system offers great potential for reducing operating costs and increasing efficiency; it may become the standard for the next generation of centralized monitoring and control systems.

Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
TRIS Case Number: 63801
TEF Number: 388
Date of Latest Information Used: October 17, 1972

VIDEOFILE TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Ampex Corporation is now commercializing a new computerized record keeping system that was partially developed under contract to NASA's Marshall Space Flight Center (66201). The original system was a unique one, incorporating the first application of professional broadcast video technology in conjunction with a new tape transport mechanism and a digital address system to direct computer indexing and tape handling. Control interfaces were handled by a small SEL computer. After completing the NASA contract, Ampex continued to develop the system primarily to improve picture resolution. In its present configuration, the system's display unit is a 1280-line vidicon tube (an improvement over the 1050-line display for NASA), a new camera for use with the vidicon tube, and an electrostatic hard copy printer. These equipment developments were accomplished in-house by Ampex.

A new division, Videofile Information Systems Division, was subsequently created by Ampex to produce and market the information system. Sales to date have exceeded \$18 million. Purchasers of the system have been the Los Angeles Sheriff's Department, the Royal Canadian Mounted Police, the Illinois Department of Enforcement, Southern Pacific Railroad, Federal Housing Administration, Kings County Hospital (Brooklyn), and two insurance companies.

Ampex anticipates the system will have a major impact in law enforcement record-keeping, retrieval and display. The firm is presently negotiating with twelve law enforcement agencies, of which three are ready to purchase the system. The Los Angeles Sheriff's Department (largest sale to date) estimated that the system would save the office \$1.5 million annually in record-keeping costs and reduce file space by 90 percent. The system will store fingerprints, photographs, and complete dossiers and make the information available for viewing on consoles at any of the fifteen county substations.

Control Numbers

Tech Brief Number: None
NASA Center: Marshall Space Flight Center
TRIS Case Number: 66201
TEF Number: 226
Date of Latest Information Used: October 6, 1971

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VIS-A-PLAN MANAGEMENT TECHNIQUE TECHNOLOGY TRANSFER EXAMPLE SUMMARY

One of the best known aerospace management procedures is the Program Evaluation and Review Technique (PERT). The usefulness of PERT, however, has been limited to the management of very large enterprises. Trans World Airlines management specialist Nathan Ranck, under contract to NASA, developed a visual display technique which reduced the complexities of PERT analyses. The technique, known as Vis-a-Plan (VISualize-a-PLAN), was used for scheduling ground support activities at Cape Kennedy. Vis-a-Plan combines the logic sequence of PERT with the time-scale method developed by Gantt; it also adds a few new features to portray an entire project rectilinearly on a time base. Each sub-task is shown, described, and integrated into the total work effort.

The Vis-a-Plan method was first described by Ranck in a paper copyrighted in 1966; in the following year, he prepared Tech Brief 67-10240, entitled "Vis-a-Plan Management Technique." The Tech Brief was subsequently described in several trade publications, including *Ceramic Age*, and a full article authored by Ranck appeared in the *Journal of Industrial Engineering*. More than 77 organizations have requested copies of the Vis-a-Plan TSP. Requests came from managers, scientists, engineers, and others working for organizations of various sizes and in many industries.

The Scott Division of A-T-O, Incorporated, a manufacturer of aviation, fire, and safety equipment in Lancaster, New York (5054), adopted the method in 1968 and is still using it. The firm had been experiencing cost and time overruns and had studied several project control methods. Vis-a-Plan fit the firm's needs and was implemented immediately on a few special projects. Within six months, all R&D engineering projects were controlled with the method; its routine use now requires only the services of a posting clerk. At least a ten percent cost reduction on each project saves the firm more than \$200,000 annually.

Late in 1967, Owens-Illinois Corporation in Toledo, Ohio (5067) applied Vis-a-Plan to several small R&D projects for which PERT was ineffective. Initially, there was some opposition as the display made some deficient performances obvious; however, it is now appreciated by all concerned. One man spends about a third of his time routinely updating the charts.

Smith and Loveless, a division of Union Tank Car Company in Lenexa, Kansas (23570), which manufactures sewage treatment equipment, evaluated the TSP during an effort to improve inventory and production control systems. Management consultants hired to assist in the project later convinced the firm's officers that a modified Gantt Chart and Critical Path Method approach would be better suited to the problem.

The University of Denver School of Engineering (28862) implemented the method to coordinate part of a multidisciplinary program involving students, faculty and research engineers. The program required patent evaluation, prototype development, market research, and introduction of an energy-absorbing safety device based on NASA patents. During initial stages, the unique nature of the project and the diverse backgrounds of the participants required a good means of project control; Vis-a-Plan was successfully used, but is no longer needed.

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Control Numbers

Tech Brief Number: 67-10240

NASA Center: Kennedy Space Center

TRIS Case Numbers: 5054, 5067, 23570, 28862

TEF Number: 28

Date of Latest Information Used: March 15, 1972

VISUAL DISPLAY PANEL AND COMPUTER INPUT/OUTPUT DEVICE TECHNOLOGY TRANSFER EXAMPLE SUMMARY

A graphic visual display panel that functions as a computer input/output device was developed at NASA's Electronics Research Center. The panel permits data entry and erasure with a probe; it has an inherent memory for use on time-shared systems; and the data can be scrutinized for error prior to entry into a computer. The display matrix consists of many gas-filled cavities inside a transparent glass case. The gas elements are maintained at a sustaining voltage, and data are entered by supplying additional voltage which illuminates selected matrix elements by ionization. An external probe (or internal electrode) fires any selected element, which remains fired until a phase reversal of the probe current causes erasure by reducing voltage in the element below the sustaining voltage. This characteristic provides an inherent memory for information storage. The device has been described by NASA in Tech Brief 70-10476.

A southwestern manufacturing firm (55508) responded to a Federal Aviation Administration (FAA) request for price quotations for improved weather information display systems. The FAA had been using a teletype operation and wanted a new, multiple display, television system to provide instantaneous updating and transmission of weather data from a central weather station. The firm demonstrated a model of a system that incorporated the NASA plasma display, but did not win the bidding. The model is being demonstrated to other potential clients, and development work is continuing.

Cinecraft, Incorporated in Cleveland, Ohio (57912) is evaluating the display for possible use as a simple counting device. The company produces industrial motion pictures and uses many small mechanical devices for such things as counting frames, notches and footage. The reliability and versatility of these devices is unsatisfactory, so the plasma display is being evaluated as a substitute and improvement. The NASA panel is also being investigated as a potential input device for computer animation.

Burroughs Corporation in McLean, Virginia (58894) sells a plasma display unit similar to that described in the TSP. A Burroughs' product manager reviewed the TSP to compare the NASA device with his product and found no differences significant enough to warrant any expensive modifications.

Control Numbers

Tech Brief Number: 70-10476
NASA Center: Electronics Research Center
TRIS Case Numbers: 55508, 57912, 58894
TEF Number: 397
Date of Latest Information Used: November 3, 1971

WEATHER SATELLITE IMAGE DISPLAY TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The Automatic Picture Transmission (APT) system developed by NASA's Goddard Space Flight Center is a unique television system that enables a weather satellite to take cloudcover pictures and automatically transmit them to simple, inexpensive ground stations as the satellite passes overhead. The APT system has been operational in the Nimbus and ESSA satellites for approximately six years.

The ground station display unit, also developed at Goddard, is an integral part of the APT system which provides both television and photographic outputs. The basic APT receiver consists of a rotatable antenna, preamplifier, FM receiver, video electronics package, oscilloscope display device, and a scope camera mounted on the oscilloscope to give a permanent display. A video tape recorder and a direct readout infrared radiometer (DRIR) conversion unit are optional parts of the receiver. The DRIR unit permits the same receiver equipment to display the satellite's infrared imagery.

NASA has published two documents that give detailed instructions for building an APT receiver: *Constructing Inexpensive Automatic Picture-Transmission Ground Stations* (SP-5079) in 1968, and *Weather Satellite Picture Receiving Stations* (SP-5080) in 1969. The second publication also provides a detailed description of the receiver's operation. Using these plans, anyone with a basic knowledge of electronics could make his own receiver with parts costing under \$500. An estimated 350 of these units have been or are being built for private, government, and research use around the world.

EMR Division of Weston Instruments, Incorporated in College Park, Maryland (431) produced the Goddard-designed receivers for NASA and has since found a commercial market for a new product line based on the NASA design. The company has sold approximately fifty units ranging in price from \$7,000 to \$14,000. The following illustrations, involving two of the EMR units, point out the fact that the primary function of the unit is in the context of a broader visual information communication network.

The National Marine Fisheries Service, an agency of the U. S. Department of Commerce located in La Jolla, California (78002), integrates the APT output with other information sources to produce two charts showing seastate and atmospheric information for the Pacific tuna fleet. The APT receiver provides approximately 25 percent of the input to the charts. This fishery/advisory information is transmitted regularly to the fleet via a radio facsimile (FAX) broadcast from La Jolla. FAX equipment has now been installed onboard forty modern tuna boats in the fleet, and more installations are planned. By using these charts, tuna fisherman have reduced the time spent searching for tuna and the variability of catch.

The National Environmental Satellite Service (NESS), part of the U. S. Department of Commerce in Washington, D. C. (78001), disseminates the imagery from its APT receiver through several networks. One involves a FAX circuit transmission to 30 of the National Weather Service stations. Another network supplies the APT video tapes to commercial wire services, which then transmit wirephotos to local newspapers and television stations. The remaining 15 Weather Service stations have their own individual APT receivers.

In addition to EMR, two other companies in the United States produce similar units. Approximately 150 commercial units are now in operation in more than 50 different countries. Most of

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these ground stations are operated by government agencies. NESS, as the coordinating agency, has received numerous letters from abroad stating the profound impact of the weather satellite information provided by the units: sea ice information for shipping, fishing, and ice-breaking operations in Canada, Iceland, Sweden, Argentina, and other countries; weather conditions which are favorable to breeding or concentration of locusts in eastern Africa; and weather forecasting in every country. The acquisition and use of APT receivers, as well as the development of related dissemination networks, indicates an expanding world-wide utilization of the weather satellite imagery and the ground display unit designed at Goddard.

Control Numbers

Tech Brief Number: None
NASA Center: Goddard Space Flight Center
TRIS Case Numbers: 431, 78001, 78002
TEF Numbers: 26, 194
Date of Latest Information Used: March 20, 1972